001-mus34 202.jpg

GREENBRIER RIVER BASIN

WEST VIRGINIA

EXHIBIT 3-1

002-mus34 203.jpg

GREENBRIER RIVER BASIN
WEST VIRGINIA

WILD AND SCENIC RIVER

Exhibit 3-2

Selection Criteria

Located Upstream of Developed Areas and Cropland.
Drainage Area Not Less Than 5 Square Miles.
Sized to Handle 4.5 Inches of Run-Off from Drainage Area.

Preliminary Flood Control Study
Breenbrier River Basin

Headwater Reservoir System

Exhibit 5-1

004-mus34 205.jpg

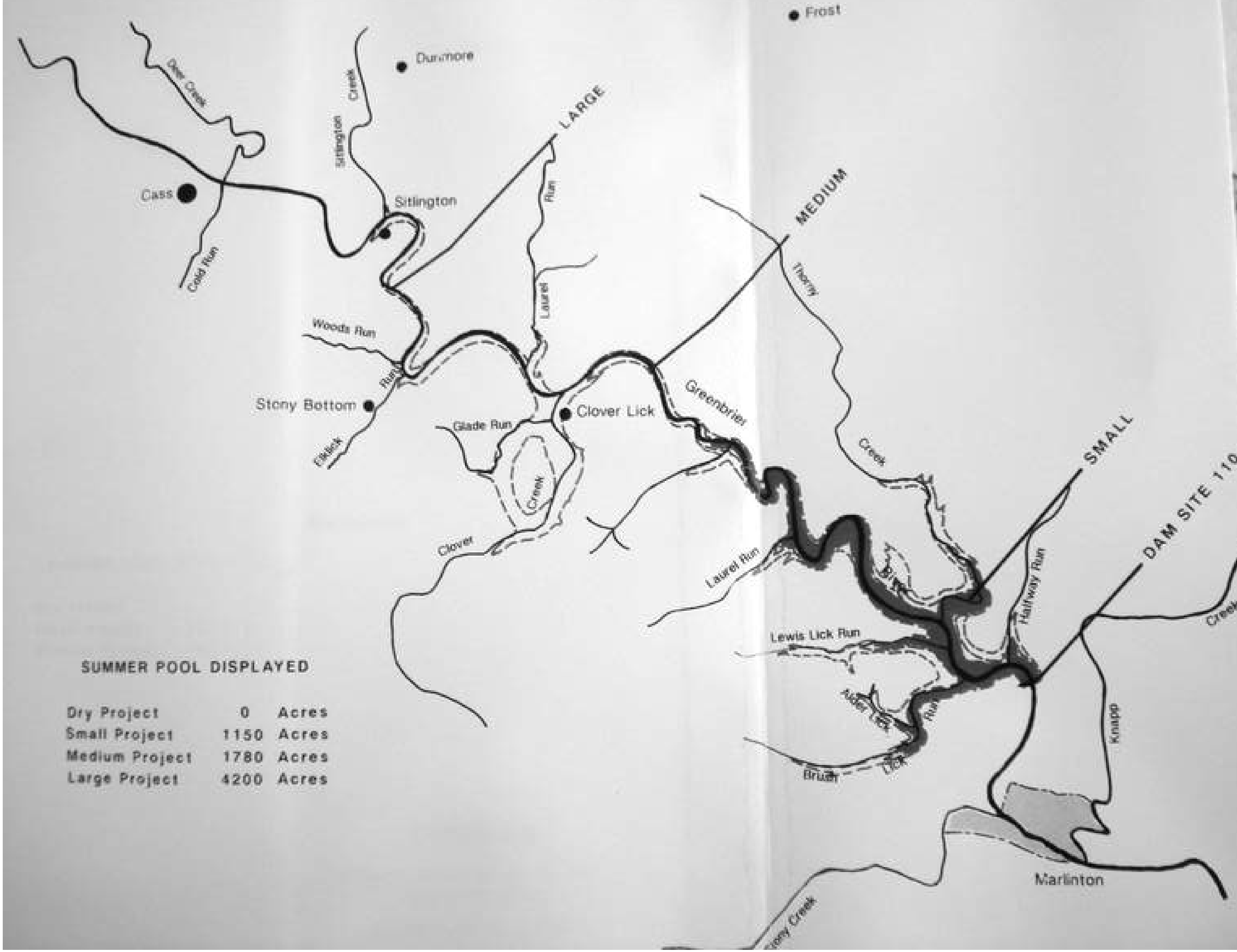
Sites

- West Fork
- Deer Creek
- Sitlington Creek
- Clover Creek
- Thorny Creek
- Knapps Creek
- D;outnat Creek

Preliminary Flood Control Study
Breenbrier River Basin

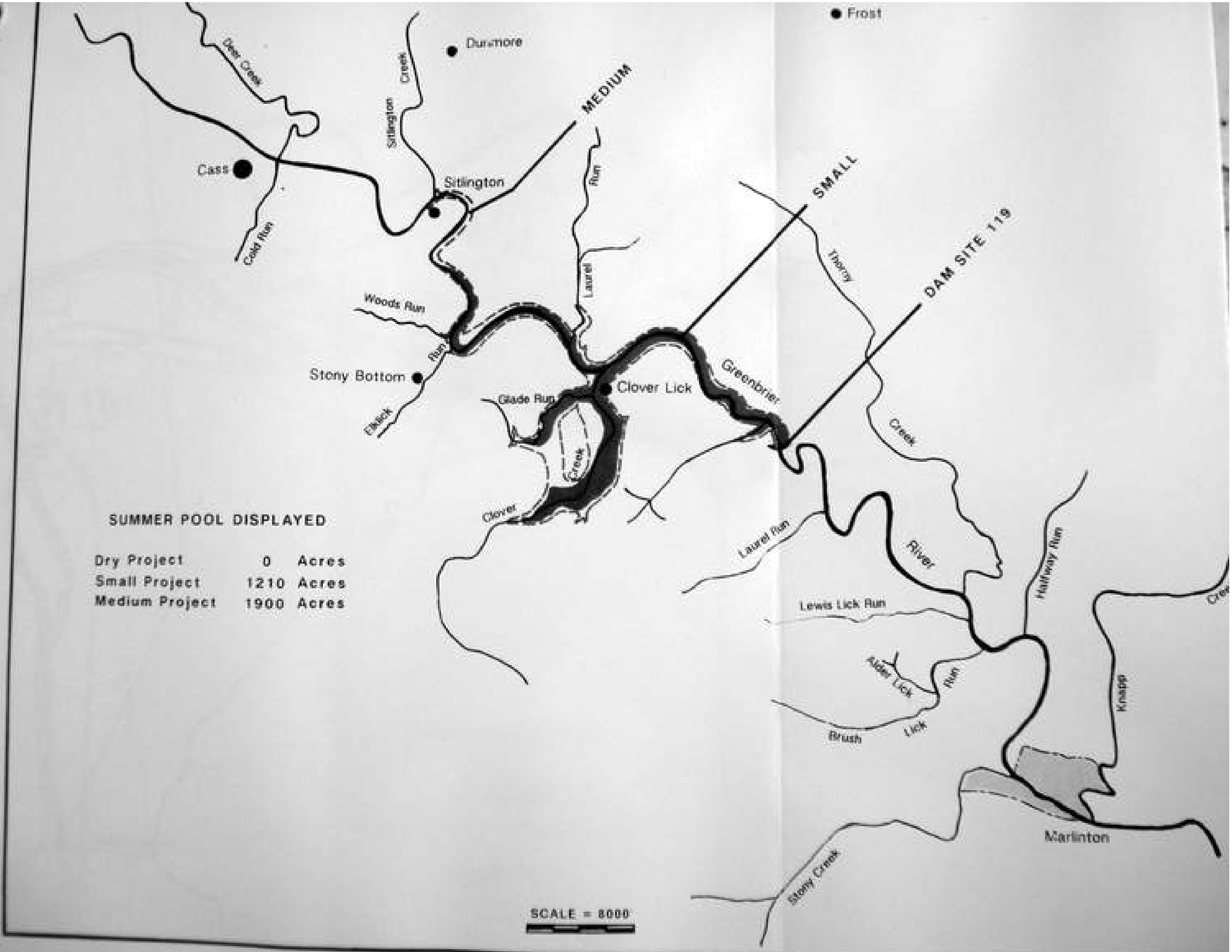
Headwater - Tributary Reservoir System

Exhibit 5 - 1a



SUMMER POOL DISPLAYED

Dry Project	0	Acres
Small Project	1150	Acres
Medium Project	1780	Acres
Large Project	4200	Acres



Frost
Dunmore
Deer Creek
Sitlington Creek
MEDIUM
Cass
Sitlington
Cold Run
Run
Laurel
SMALL
DAM SITE 119
Thorny
Woods Run
Run
Stony Bottom
Elklick
Glade Run
Clover Lick
Greenbrier
Creek
Creek
Clover
SUMMER POOL DISPLAYED
Dry Project 0 Acres
Small Project 1210 Acres
Medium Project 1900 Acres
Laurel Run
River
Halfway Run
Lewis Lick Run
Alder Lick
Run
Knapp
Brush
Lick
Marlinton
Stony Creek
SCALE = 8000

007-mus34 208.jpg

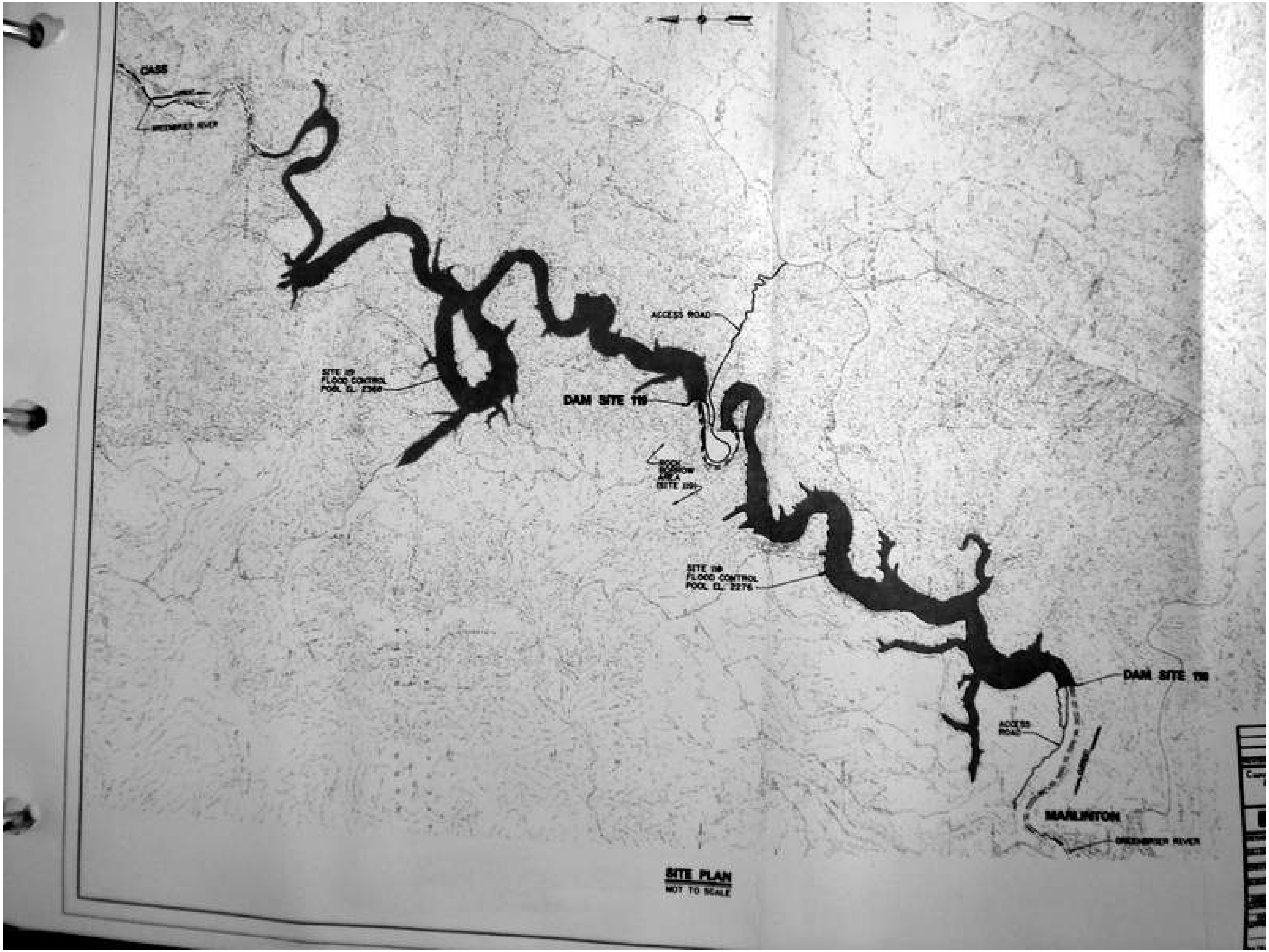
LEVEE ALIGNMENT

MARLINTON

LOCAL PROTECTION PROJECT

EXHIBIT 5-6

008-mus34 209.jpg



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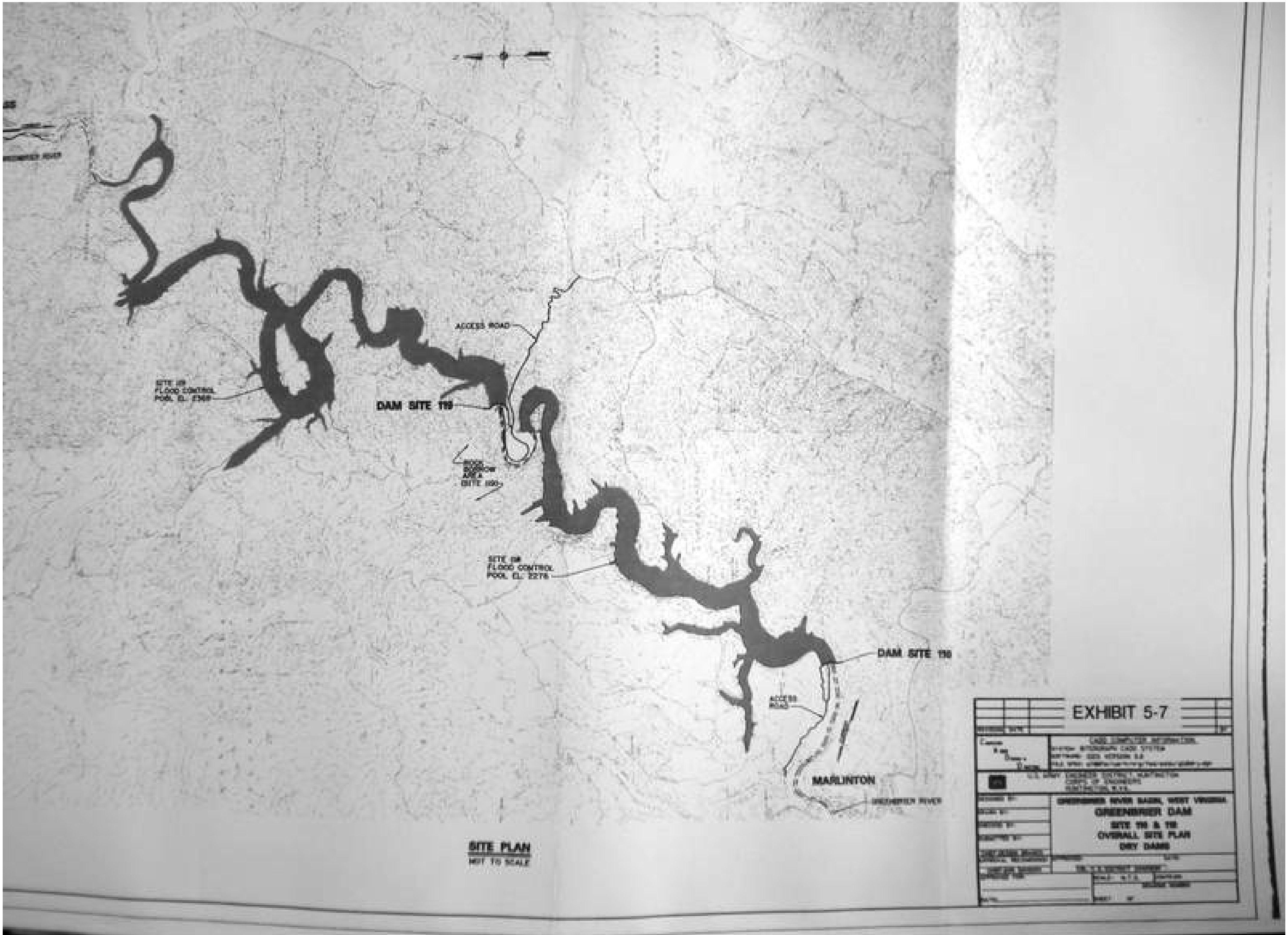

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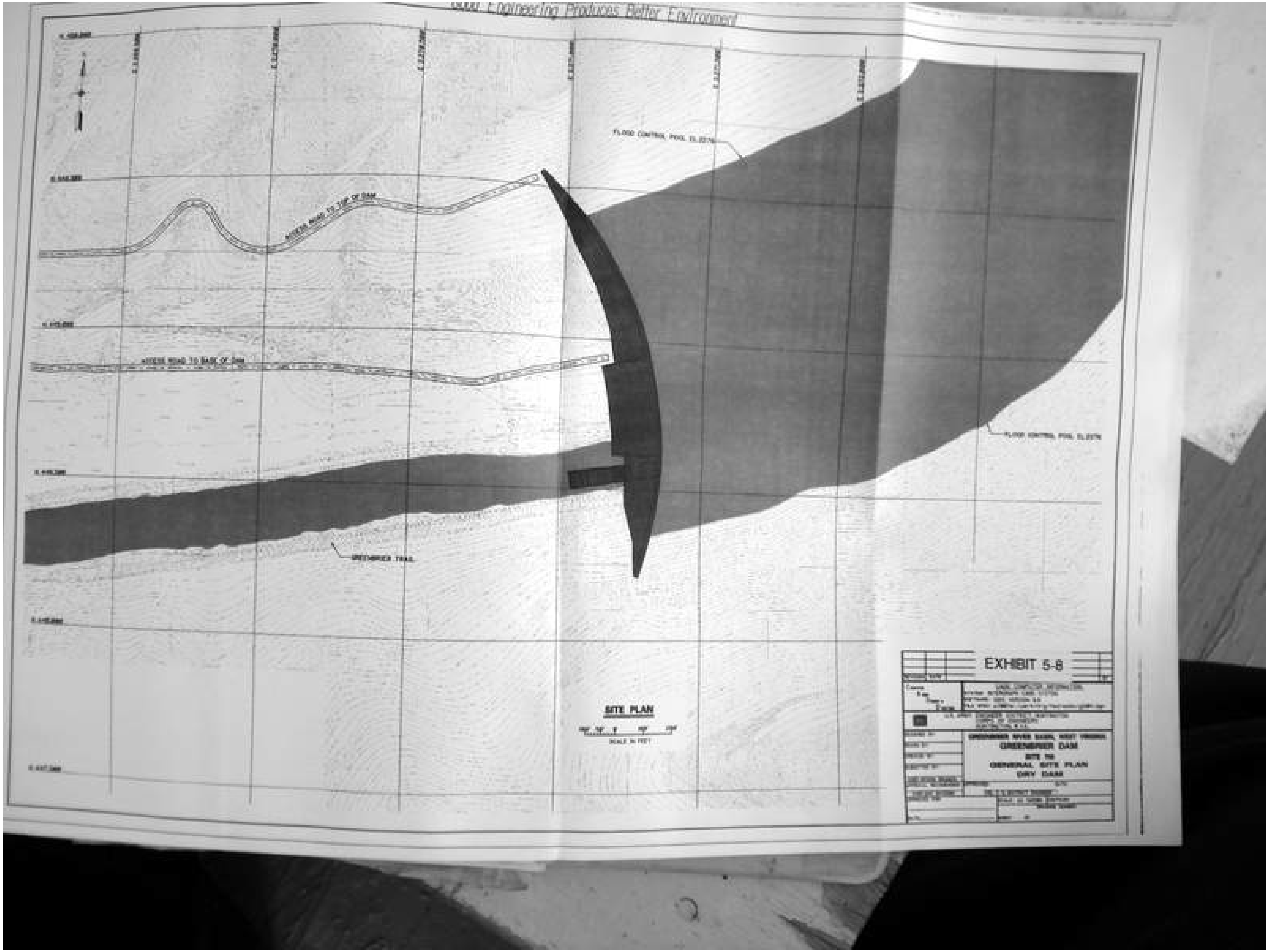

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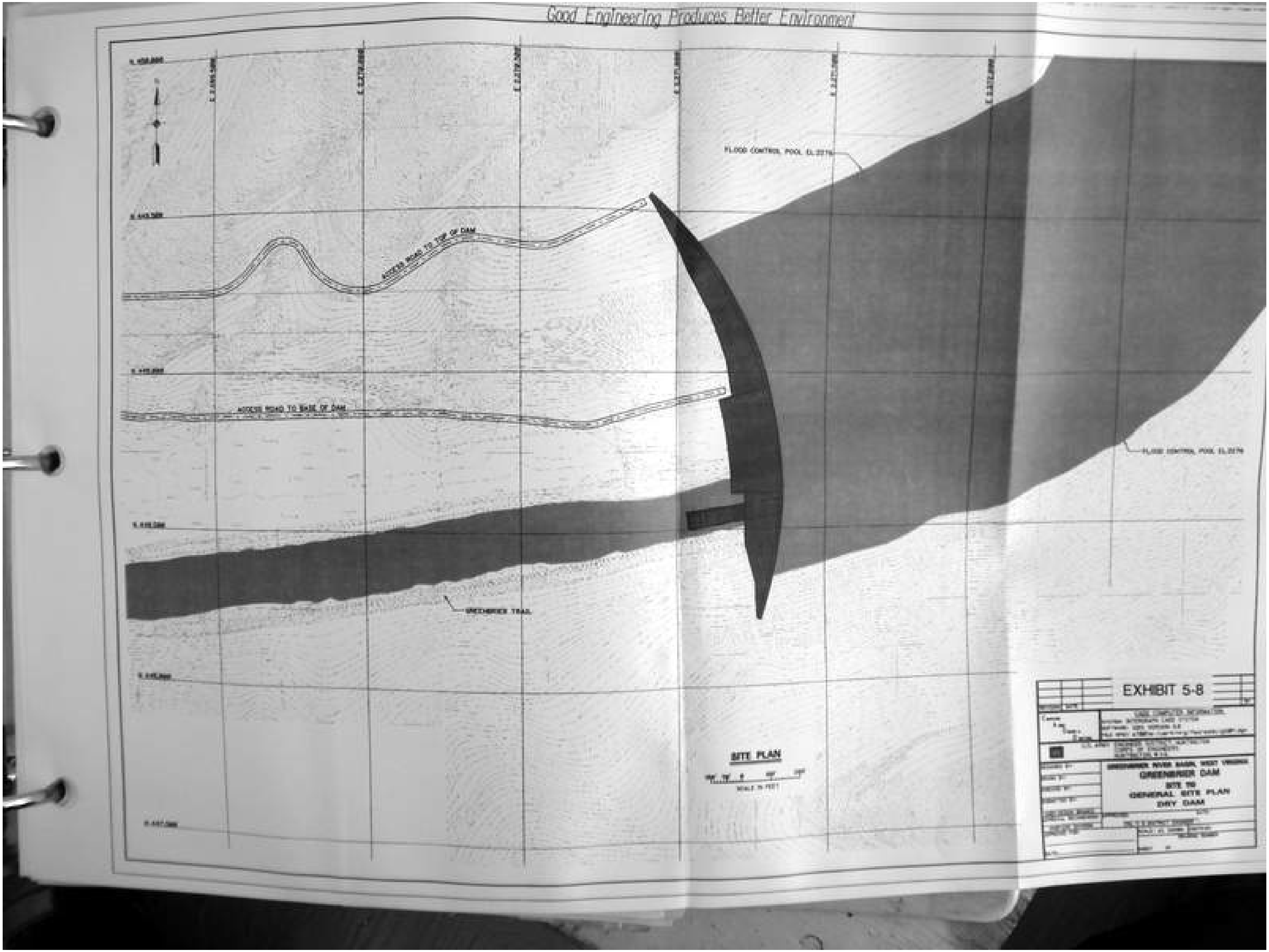

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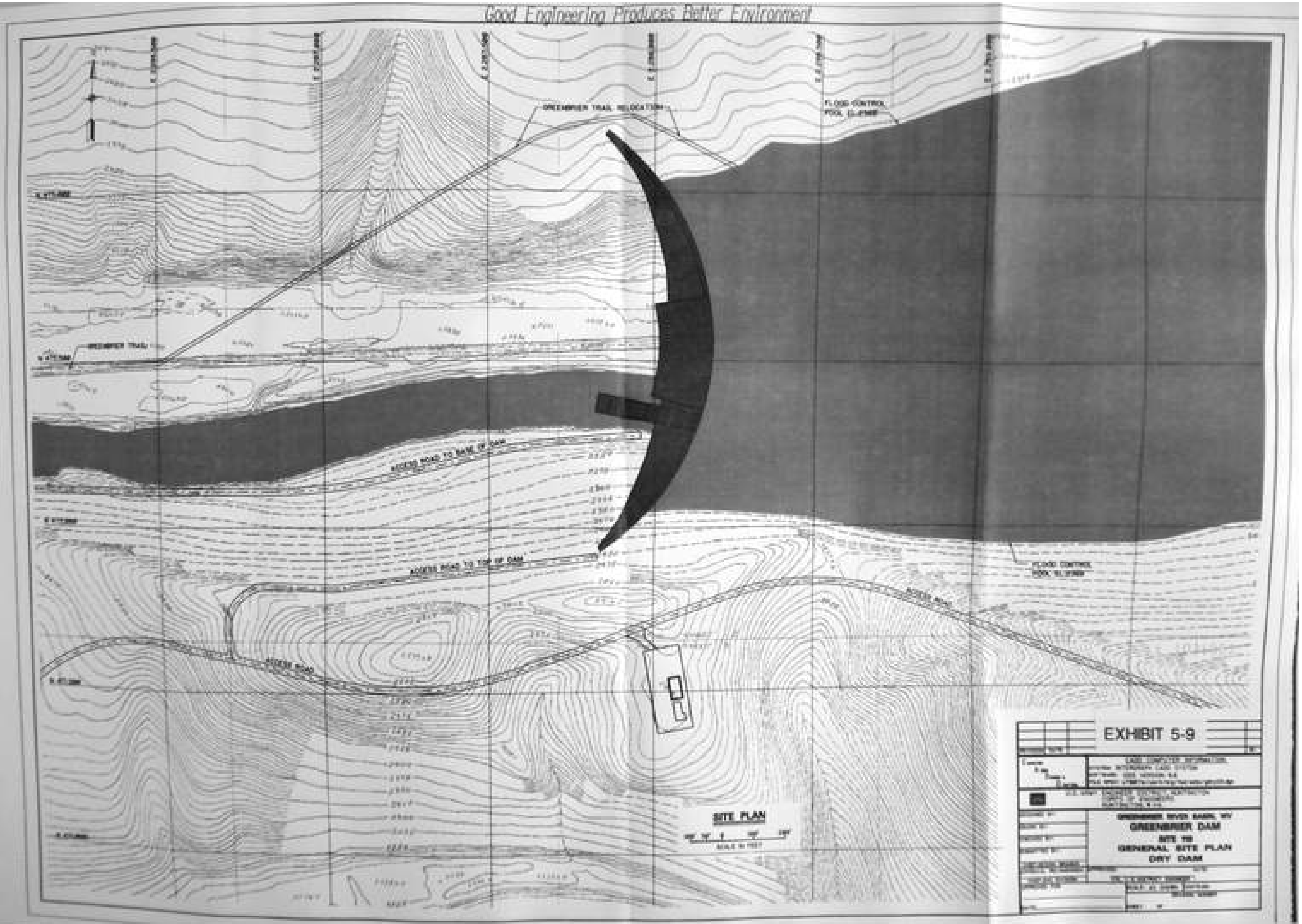

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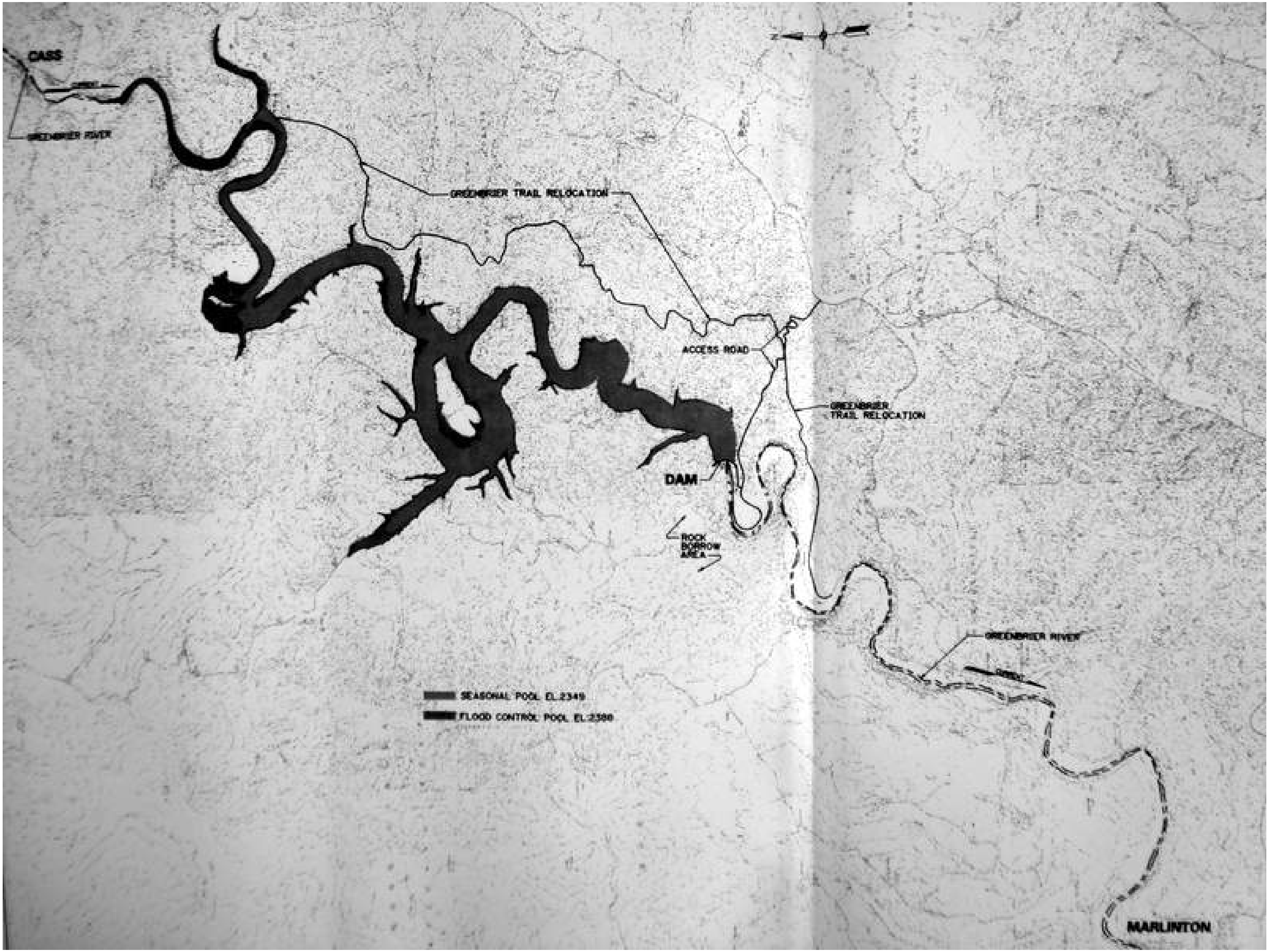

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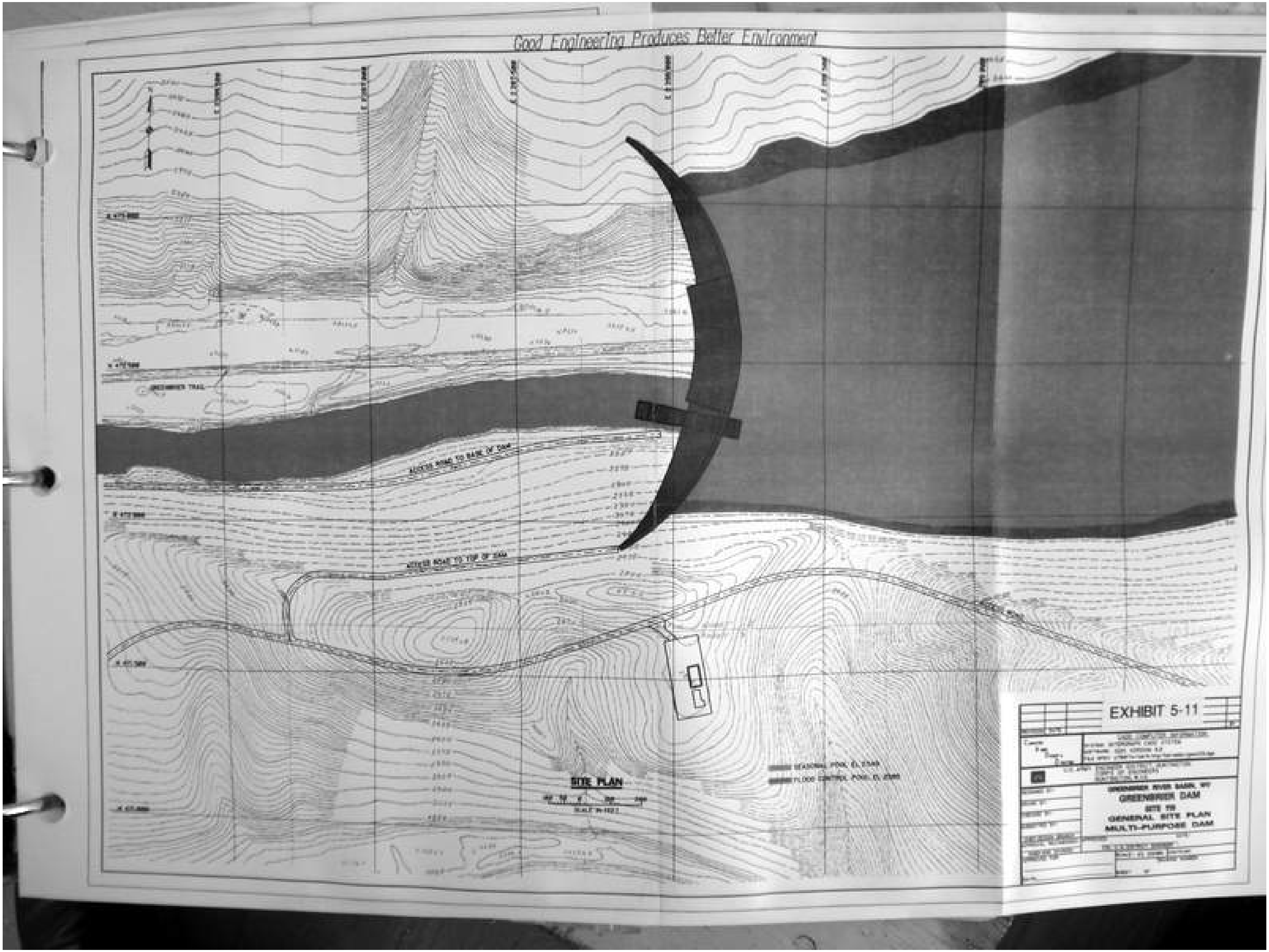

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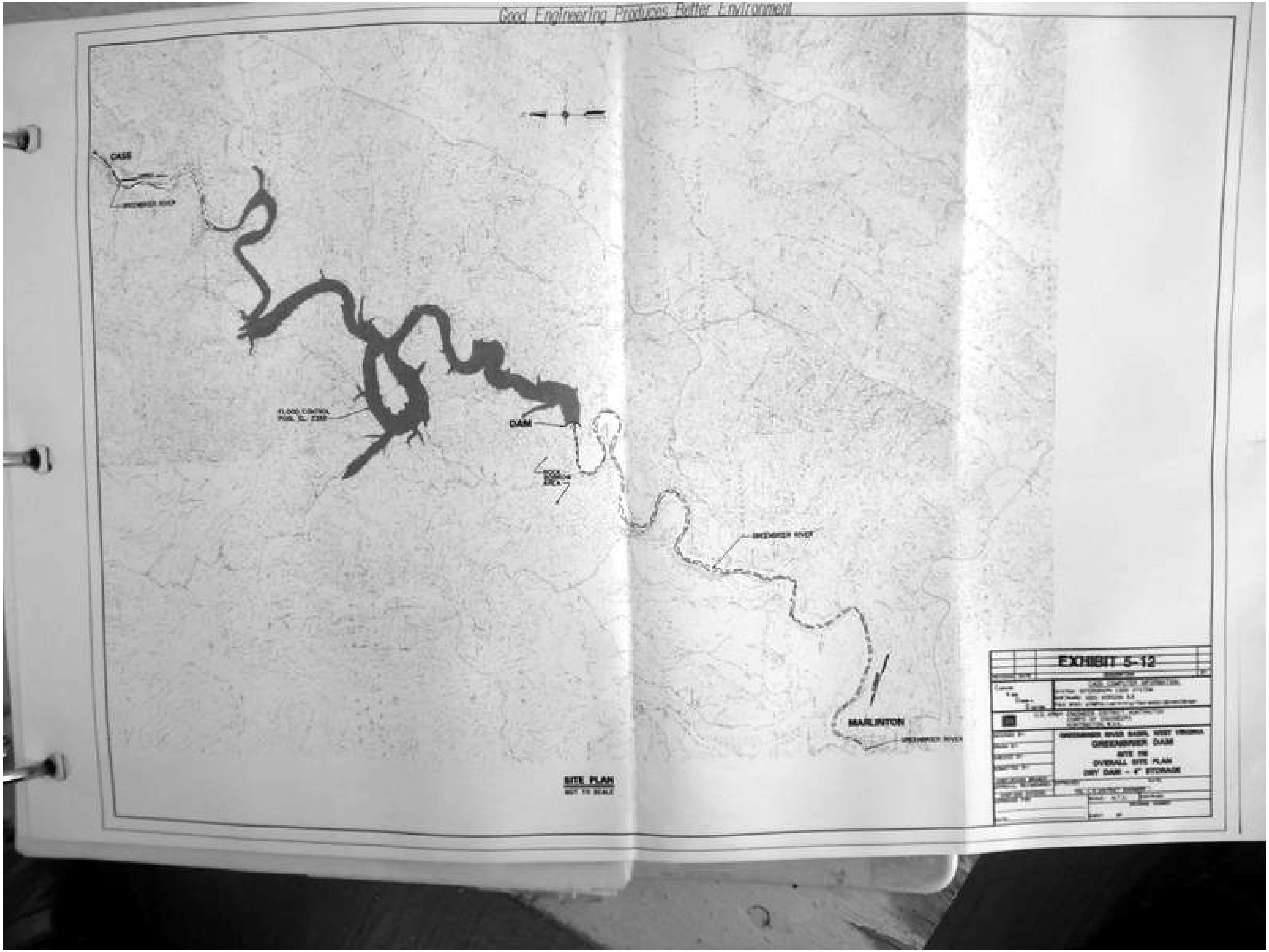
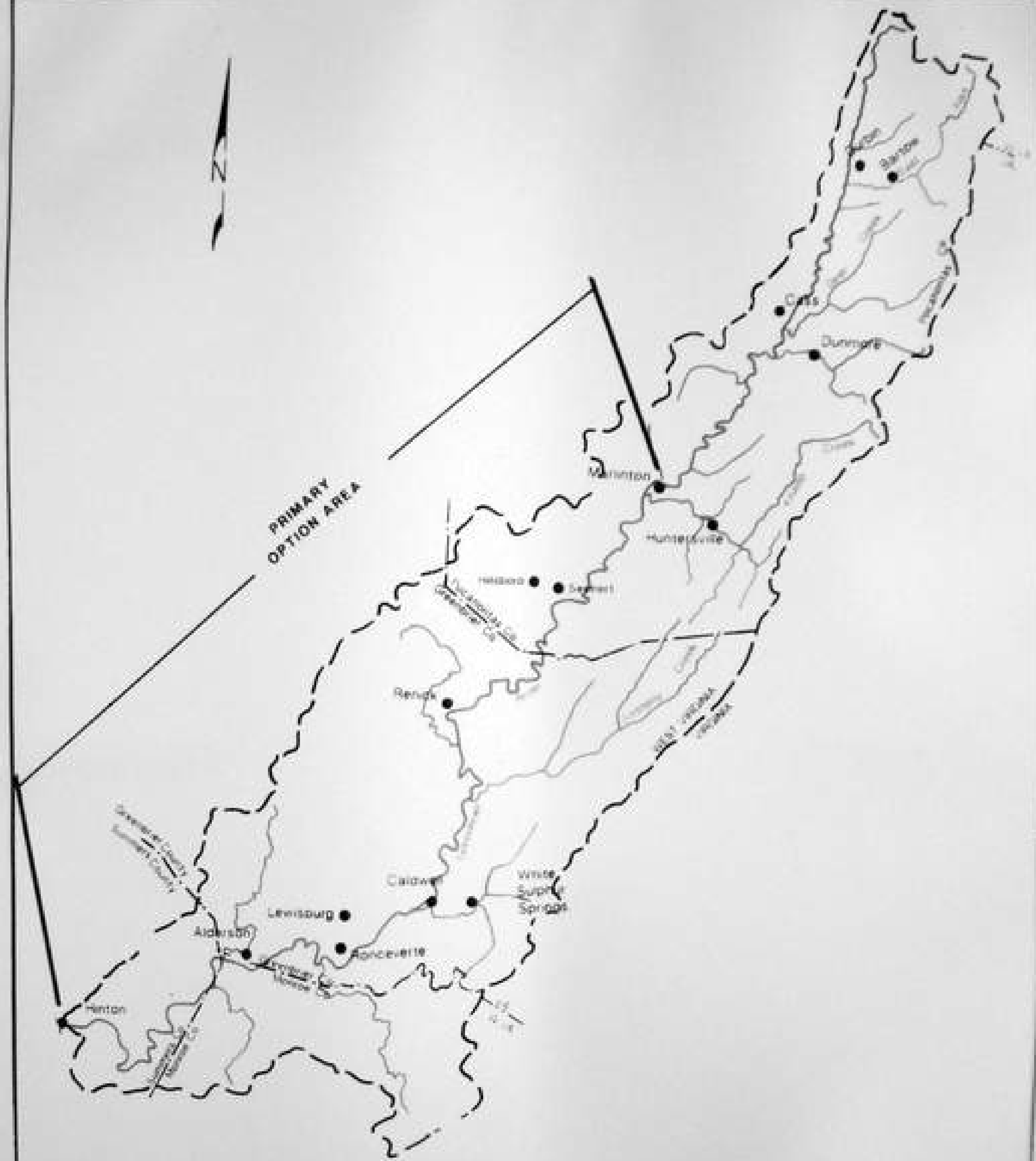
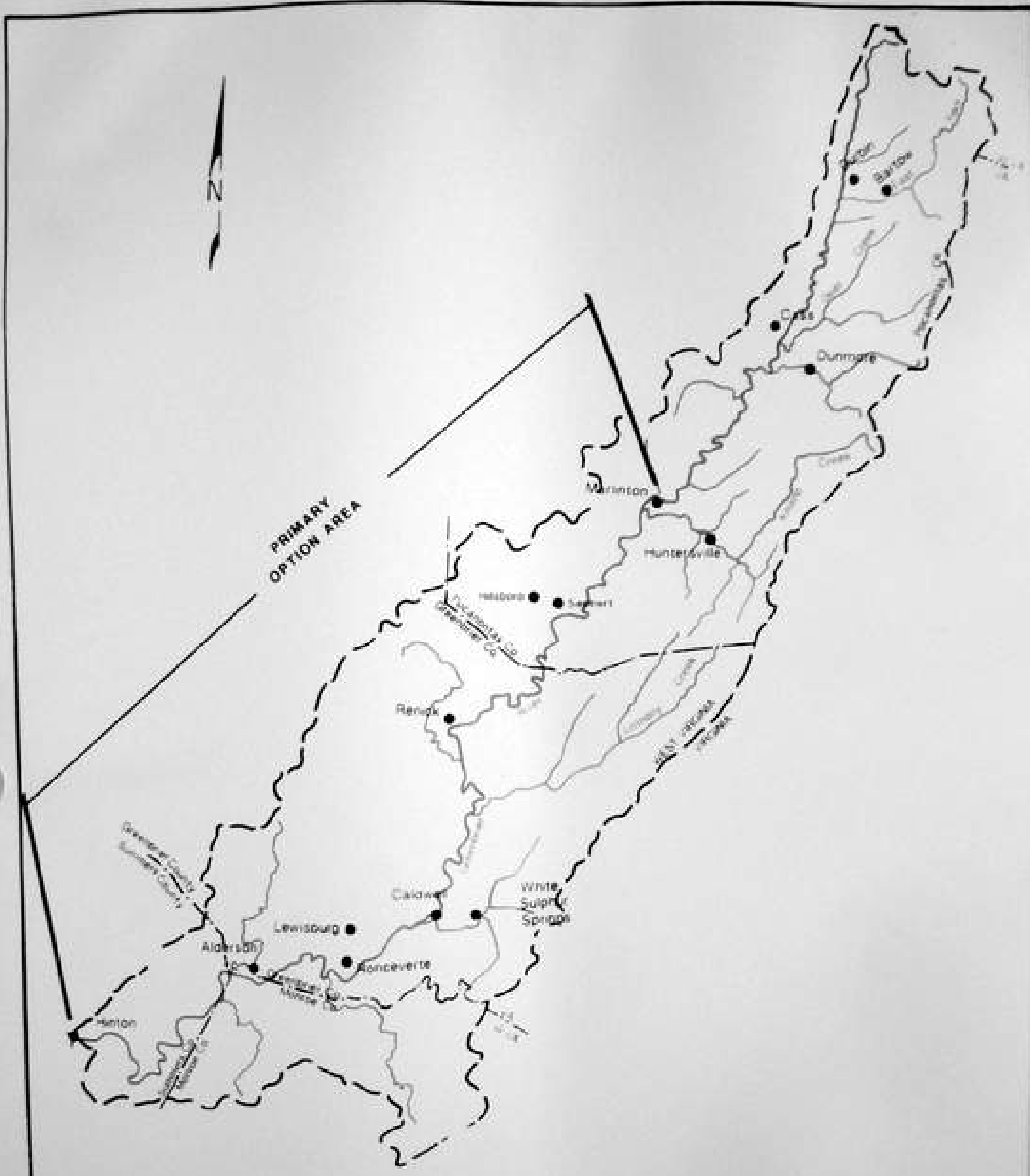




GREENBRIER RIVER BASIN
WEST VIRGINIA

EXHIBIT 5-14



GREENBRIER RIVER BASIN
WEST VIRGINIA

EXHIBIT 5-14

Greenbrier River
Basin Study

GREENBRIER DAM

APPENDIX A - ENGINEERING, DESIGN AND COST

1. INTRODUCTION

a. Purpose and Scope. The purpose of this Evaluation Study is to evaluate alternatives that would reduce or eliminate flooding within the Greenbrier River Basin and to determine if there is a Federal interest in proceeding with the feasibility study. This appendix contains the engineering, design and cost data to support the structural plans presented in the Evaluation Report. Included are descriptions of the selected mainstem impoundment alternatives, associated real estate and relocations requirements and cost estimates for each alternative. A more detailed, feasibility-level design and a total project cost estimate will be completed in the feasibility study phase, contingent upon the determination of a project in the Federal interest as detailed in the Evaluation Report.

b. Study Authority. Authority for the study was granted by Resolution of the Public Works Committee of the U.S. House of Representatives on 10 May 1962. Following the disastrous flood of November 1985, local protection studies underway at Marlinton, West Virginia, were re-directed toward assessing structural measures for reducing flood damages throughout the Greenbrier River Basin.

c. Location of Project. The Greenbrier River Basin is located in southeastern West Virginia and has a drainage area of 1641 square miles. From its source in Pocahontas County to its confluence with the New River in Summers County, the river flows 167 miles through four West Virginia counties -- Pocahontas, Greenbrier, Monroe and Summers. Potential Greenbrier Dam sites are located in Pocahontas County above the community of Marlinton.

2. SITE INVESTIGATIONS

a. Original Site Reconnaissance. The Preliminary Study on the Greenbrier River Basin, completed in February 1988, met the basic requirements of a Reconnaissance Study. An array of

alternatives was considered including head-water dams, tributary dams, mainstem dams, local protection projects, floodproofing and floodplain evacuation of structures. Mainstem dams on the Greenbrier River between Marlinton and Cass, WV, were the only alternatives that indicated a potential for economic feasibility.

Four potential dam sites were identified on the mainstem of the Greenbrier River between Marlinton and Cass, WV. Various types of dams were evaluated at these sites, and it was determined that roller compacted concrete (RCC) dams were the most economical. The RCC dams investigated at that time were of gravity type. It was further determined that Sites 110 and 119 exhibited the most potential with benefit-to-cost ratios above unity.

b. Site 110. Site 110 is located approximately 2 miles upstream of Marlinton, WV, on the mainstem of the Greenbrier River. The river bed is at elevation 2,132. The left abutment is relatively steep and extends above elevation 2,680; the right abutment is less steep and extends above elevation 2,480. Access to the site is at stream elevation on the left abutment via the Greenbrier Trail, and on the right abutment via a private drive and Airport Road which intersects U.S. Route 219.

c. Site 119. Site 119 is located approximately 11 miles upstream of Marlinton, WV, on the mainstem of the Greenbrier River. The river bed is at elevation 2,223. The abutments are moderately steep with the left extending above elevation 2,480 and the right above elevation 2,800. Access to the site is at the stream level on the right abutment via the Greenbrier Trail.

3. PROJECT PLAN

The primary focus of this Evaluation Study was on a flood control (dry) dam at Sites 110 and 119 and a multi-purpose (wet) dam at Site 119 that would provide 5" of flood control storage. The option of an RCC gravity dam was revisited to optimize the previous preliminary design but it was ruled out in favor of an RCC arch-gravity dam, which offered approximately 15% savings in the amount of concrete and required excavation.

The initial phase of the Study was directed toward a comparison of the dry dam sites. This phase focused on the construction activities and material quantities that would vary with each particular site. This approach, as discussed further in Section 6 of this appendix, resulted in the selection of a dry dam at Site 119. The second phase of the study consisted of the development of both a dry and a wet dam at Site 119. After the development of costs and associated benefits for these alternatives, it became apparent that the optimum amount of flood control storage was less than the 5" as determined in the

previous study. Additionally, based upon further analysis of the existing design, it was determined that several items could be modified for additional cost savings. Based upon this information, the District initiated a third phase of the study which analyzed a smaller dry dam at Site 119. This analysis included innovative design measures as discussed in Section 8. Total project costs are discussed in Section 15 of this appendix.

4. TERMINOLOGY

Terminology used in describing an arch-gravity dam and roller compacted concrete construction is defined below:

a. Arch-Gravity Dam

An ARCH-GRAVITY dam is curved in plan only and has a vertical cross-section similar to that of a gravity dam except with a steeper downstream face. The stability of this type of dam is achieved by the combined effect of its mass and the arch action that transfers a portion of the resultant forces into the abutments. The layout of the arch-gravity dam is developed by establishing the crown cantilever geometry, the axis radius and the line of centers as defined below.

The CROWN CANTILEVER is a vertical section located in the deepest part of the valley and defines the vertical control of both the upstream and downstream surfaces of the arch-gravity dam.

The AXIS of an arch-gravity dam is a circular curve in the horizontal plane and is defined by the intersection of the dam crest and the upstream face

The LINE OF CENTERS is a line in space which is the locus of centers of the circular arcs describing either the downstream or the upstream face of an arch-gravity dam.

The REFERENCE PLANE is a vertical plane which passes through the crown cantilever and the axis center.

A CANTILEVER ELEMENT is a section of an arch-gravity dam defined by two vertical, radial planes.

An ARCH ELEMENT is a portion of an arch-gravity dam bounded by two horizontal planes 1 foot apart.

A SINGLE-CENTERED or CIRCULAR arch-gravity dam is one whose horizontal cross-sections are defined by two radii (i.e., one upstream radius and one downstream radius).

A UNIFORM THICKNESS ARCH is an arch element whose thickness remains constant from the reference plane to the abutments.

b. Roller Compacted Concrete (RCC)

RCC is a no-slump, extremely dry concrete that can be rapidly placed and consolidated by earth moving and embankment compaction equipment.

BEDDING MORTAR, approximately 1/2 inch thick, is placed between the successive RCC lifts to assure bonding and water tightness at the horizontal joints.

FACING ELEMENTS are of conventional concrete and may be either cast-in-place or pre-cast. They are used on the exposed surfaces of the dam to prevent deterioration of the RCC due to freeze-thaw cycles and may be used as a liner for gallery walls.

5. DESCRIPTION OF DAM AND TYPE OF CONSTRUCTION

Due to its arch action, an arch-gravity dam is more slender and has a narrower base than a gravity dam of equal height, which provides savings in the amounts of construction material and excavation. For this study on the 5" flood control storage alternatives, a dam with a vertical upstream face was used while a somewhat conservative slope of 0.5 h. to 1.0 v. was chosen for the downstream face. The downstream slope of the spillway section was chosen to be as steep as possible to minimize the material quantities. The top width of the dam was set at 15 feet, and was determined by factors including structure stability, constructibility, and post-construction access. See Exhibits No. 2A, 3A and 5A for non-overflow and spillway cross-sections. After establishing the geometry of the arch-gravity dam for each specific site, a preliminary stress analysis was performed utilizing the Arch Dam Stress Analysis System (ADSAS), a computerized version of the trial load method of analysis developed by the U.S. Bureau of Reclamation.

Both dam sites, 110 and 119, lend themselves well to RCC placement operations because of their wide valley bottoms and moderate abutment slopes. There is ample space to maneuver the spreading and compaction equipment, which offers a potential for efficient RCC construction. Both sites also provide sufficient area for staging and storage of construction materials. An RCC dam is raised by placing 12 to 24-inch lifts of "zero-slump" concrete in 6-inch layers by earthwork equipment that remixes and redistributes the material while providing most of the required compaction. Final compaction is accomplished using vibratory rollers. The use of such equipment results in significantly higher production rates than those possible with the conventional

methods of large volume placements. In order to maximize bond and water tightness at the interface between the successive RCC lifts, a thin layer of bedding mortar is placed immediately prior to the next RCC lift. A conventional concrete facing is used mainly to protect the RCC from the effects of freezing and thawing. This facing can be cast-in-place concurrently with the RCC lifts, or installed in pre-cast concrete panels. Gallery construction is typically accomplished using gravel or sand-fill replacement, or conventional concrete facing. When locating the drainage gallery in an RCC dam, adequate space must be provided for RCC placing and compaction equipment in all areas adjacent to the gallery. Also, to keep the disruptions of RCC placement to a minimum, the number and locations of the contraction joints must be optimized.

6. DRY DAM SITE SELECTION

a. General. As previously stated, the initial phase of the Evaluation Study focused on the identification of the most cost effective site for a dry dam that would provide 5" of flood control storage. This comparison was limited to the items that varied for each dam site. These variable items included real estate acquisition, access roads, and dam quantities such as excavation, foundation treatment, and construction materials. The rationale for this approach was primarily due to fiscal and time constraints.

For the purpose of this initial evaluation, it was assumed that the cost of the following items would be similar for either dam site: outlet works; operations building; buildings, grounds and utilities; construction clearing; relocations; power; engineering and design; construction management; and mitigation. These items were not developed for this initial cost comparison. See Exhibit No. 1 for the overall site plans for both dam sites. Pertinent data for the dry dams are listed below in Table 1.

TABLE 1 - Dry Dam Pertinent Data

Dry Dam Site	Top of Dam Elevation (NGVD)	Spillway		Crest Length Along Axis (ft)
		Width(ft)	Crest El.	
110	2324.5	340	2276.0	1,491.2
119	2413.5	345	2368.0	1,476.5

b. Site 110.

i. Dam. The crest length along the axis measures 1,491.2 feet. The dam foundation has a minimum elevation of 2105, and the top of dam is at elevation 2324.5. This site requires a 340-foot-wide spillway with the crest at elevation 2276. The aggregate source for this site is a commercial quarry located 10-miles from the project site. See Exhibit No. 2 for the general site plan.

ii. Access Roads. Access to the base of dam requires 1.7 miles of an existing private road to be upgraded to a 24-foot-wide aggregate haul road, and the access to top of dam requires 0.4-miles of a 24-foot-wide aggregate haul road to be constructed through a wooded area. Upon completion of construction the haul roads will be used by the operations and maintenance personnel for access to the dam.

c. Site 119.

i. Dam. The crest length along the axis measures 1,476.5 feet. The dam foundation has a minimum elevation of 2200, and the top of dam is at elevation 2413.5. This site requires a 345-foot-wide spillway with the crest at elevation 2368. The aggregate source is a borrow area above the right abutment of the dam, 0.8-mile from the site. The aggregate will be quarried and transported to the site by a conveyor system. See Exhibit No. 3 for the general site plan.

ii. Access Roads. Access to the top and the base of dam requires that one mile of the Kronmiller Trail be upgraded to a 24-foot-wide aggregate haul road with an additional 3.3-miles of the aggregate haul road to be constructed through a wooded area. Upon completion of construction the haul roads will be used for operation and maintenance access to the dam.

Table 2 - Dry Dam Cost Comparison

Variable Features	Site 110	Site 119
Real Estate	$ 4,800,000	$ 8,300,000
Dam Quantities:		
Earthwork	$ 2,424,000	$ 1,594,000
Foundation Treatment	$ 2,176,000	$ 2,006,000
RCC & Conv. Concrete	$29,569,000	$25,113,000
Access Roads	$ 564,000	$ 1,299,000
Total - Variable Features	$39,533,000	$38,312,000

d. Site Selection. As shown in Table 2, the most cost effective dry dam site is Site 119 due to lower dam construction quantities. Also, due to the proximity of the aggregate source, the unit price of aggregate is less at Site 119. Site 110 requires less real estate and shorter access roads, but the resulting cost savings were negated by the larger dam construction quantities required at this site. The estimated savings in selecting Site 119 over Site 110 are approximately $1.2 million, based on the variable project features for dry dams at either site. Therefore, Site 119 was chosen for the development of the 5" flood control storage dam alternatives.

7. 5" STORAGE DAM ALTERNATIVES

a. General. The 5" flood control storage dam alternatives include a multi-purpose (wet) dam and a flood control (dry) dam, both at Site 119. Pertinent data for these dams are listed in Table 3.

TABLE 3 - 5" Storage Dam Alternatives Pertinent Data

Dam Type and Site	Top of Dam Elevation (NGVD)	Spillway		Crest Length Along Axis
		Width(ft)	Crest El.	
Flood Control (Dry) Site 119	2413.5	345	2368.0	1,476.5 ft
Multi-Purpose (Wet) Site 119*	2427.0	440	2388.0	1,576.1 ft

*Seasonal Pool Elevation 2349.0

b. Site 119 Flood Control Dam.

i. Dam. The dry dam features were described in Section 6.c., above. Exhibits No. 1 and 3 depict the overall and general site plans. The non-overflow section will require 223,000 cubic yards of RCC and 43,100 cubic yards of conventional concrete. The concrete aggregate can be quarried above the right abutment of the dam and transported to the site by a conveyer over a 0.8-mile distance. Potential aggregate sources are further discussed in Section 12 of this appendix.

ii. Spillway. The overflow section will consist of an ogee type ungated spillway with a flip-bucket energy dissipator. A concrete splash pad will be provided for downstream scour protection and to prevent undermining of the foundation during spillway releases. The overflow section will require 206,000

cubic yards of RCC and 24,000 cubic yards of conventional concrete.

iii. Outlet Works. The outlet works will consist of three 8-ft by 15-ft sluices controlled by caterpillar service gates, housed in and operated from a downstream control structure. Immediately upstream of each service gate a recess will be provided for an emergency gate that will be shared among the sluices. Aluminum stop logs will be provided upstream for maintenance closure of the sluices. A conventional hydraulic-jump type stilling basin will be used for downstream energy dissipation of sluiceway flows.

iv. Access Roads. The aggregate haul roads for this site, described above in Section 6, will be retained for operations and maintenance of the project, but not for recreational or public use as the maximum slopes on these roads will approach 20%. The Resident Engineer's office and the materials lab will become the operations and maintenance buildings upon completion of construction and will be accessible via the access road.

c. Site 119 Multi-Purpose Dam.

i. Dam. The crest length along the axis of the dam measures 1,576.1-ft. The top of dam is at elevation 2427.0. The dam will be founded on suitable rock with the deepest section at elevation 2200. See Section 11 of this appendix for a discussion of the foundation rock. Exhibits No. 4 and 5 show the overall and general site plans. The non-overflow section will require 229,000 cubic yards of RCC and 43,500 cubic yards of conventional concrete. The aggregate source is as described above for the dry dam alternative at this site.

ii. Spillway. The overflow section will consist of a 440-foot-wide ungated ogee spillway with a crest elevation of 2388. For energy dissipation, a flip-bucket will be used in conjunction with paving of the downstream area for scour protection. The overflow section will require 267,000 cubic yards of RCC and 30,200 cubic yards of conventional concrete.

iii. Outlet Works. The outlet works will consist of a conventional intake tower extending to the top of dam. The intake structure will have two wet wells with ten 4-ft by 4-ft selective withdrawal intakes. The outlet consists of three 8-ft by 15-ft sluices controlled by tandem emergency and service caterpillar gates. A bulkhead will be provided upstream for maintenance closure of the sluices. Downstream energy dissipation will be effected by a conventional hydraulic-jump type stilling basin.

iv. Access Roads. The aggregate haul roads for this site are described above in Section 7.b.

8. 4" STORAGE DRY DAM ALTERNATIVE

a. General. After an initial analysis of engineering and economic data, it became apparent that the optimum size dam was no longer one that would contain 5" of flood control storage, but some dam of a smaller size. Based upon the initial benefit stream, a dry dam containing 4" of flood control storage would present the best opportunity for economic feasibility. This third phase of the study utilized innovative design and cost reduction measures such as minimizing the RCC non-overflow dam section, removal of the foundation grout curtain, and designation of the Greenbrier Trail as construction and operation site access. Pertinent data for this dam is listed in Table 4.

TABLE 4 - 4" Storage Dry Dam Alternative Pertinent Data

Dam Site	Top of Dam Elevation (NGVD)	Spillway		Crest Length Along Axis (ft)
		Width(ft)	Crest El.	
119	2407.0	310	2358.0	1,425.9

b. Innovative 4" Storage Flood Control Dam.

i. Dam. The arch-gravity dam, as discussed in Section 5, was modified through the following design refinements:

(1) The crest of the dam is at the maximum flood control pool elevation (El. 2404), and a 3-feet high parapet wall brings the top of dam to the elevation shown in Table 4. The hydrostatic loading begins at the crest of the dam (top of pool) so the parapet wall is needed only to provide freeboard for wave action.

(2) The crest width is 15 feet as in other alternatives, but the downstream face of the dam is vertical for the top 25 feet and then has a slope of 0.45 h. to 1.0 v. This cross-sectional shape makes more efficient use of the concrete. The dam structural analysis results show relatively low stresses. Further refinement of the shape must wait until more detailed geological information is available.

(3) A foundation grout curtain for a dry dam is not required since a permanent pool will not be maintained. Seepage under a concrete arch-gravity dam does not threaten the dam's integrity.

These measures provide a 15% savings in the quantities of construction material and excavation. See Exhibit No. 7A for non-overflow and spillway cross-sections.

The crest length along the axis measures 1,425.9 feet. The dam foundation has a minimum elevation of 2200, and the top of dam is at elevation 2407.0. This site requires a 310-foot-wide spillway with the crest at elevation 2358. Exhibits No. 6 and 7 depict the overall and general site plans. The non-overflow section will require 145,000 cubic yards of RCC and 41,100 cubic yards of conventional concrete. The concrete aggregate can be quarried above the right abutment of the dam and transported to the site by a conveyer over a 0.8-mile distance. Potential aggregate sources are further discussed in Section 12 of this appendix.

ii. Spillway. The overflow section will consist of an ogee type ungated spillway with a flip-bucket energy dissipator. A concrete splash pad will be provided for downstream scour protection and to prevent undermining of the foundation during spillway releases. The overflow section will require 179,100 cubic yards of RCC and 19,900 cubic yards of conventional concrete.

iii. Outlet Works. The outlet works will consist of three 8-ft by 15-ft sluices controlled by caterpillar service gates, housed in and operated from a downstream control structure. Immediately upstream of each service gate a recess will be provided for an emergency gate that will be shared among the sluices. Aluminum stop logs will be provided upstream for maintenance closure of the sluices. A conventional hydraulic-jump type stilling basin will be used for downstream energy dissipation of sluiceway flows.

iv. Access Roads. In this alternative the Greenbrier Trail will be used as site access for construction and operations of the project. Vehicular traffic can access Site 119 from either downstream or upstream. Construction material and equipment will access the site from upstream. The Resident Engineer's office and the materials lab will become the operations and maintenance buildings upon completion of construction and will be located on the right abutment, overlooking the dam adjacent to the rock borrow area. Above dam access and relocation of the Greenbrier Trail around the dam will be constructed on abandoned construction haul roads. Access to the gate house will be from an access road that extends from the Greenbrier Trail over the spillway splash pad to the gate house and stilling basin.

9. HYDROLOGY AND HYDRAULICS

Addendum 1 sets forth in detail, the hydrology of the drainage basin and the hydraulic design of the project features. The hydrologic data includes climatology, streamflow, historic floods, flood probability, and Probable Maximum Flood and Standard Project Flood development. The hydraulic design studies

involved development of water surface profiles with and without the dam, spillway rating and optimization, outlet works design, flood routings for determination of top-of-dam elevations, determination of tailwater rating curves, and diversion studies.

10. SURVEYING AND MAPPING

The evaluation study design was conducted using existing mapping of the dam sites and USGS quadrangle (quad) sheets. The quad sheets are to a scale of 1-inch = 200-ft with a contour interval of 40-ft and dated 1977. Site 110 mapping was flown in April 1981 to a scale of 1-inch = 50-ft with a contour interval of 2-ft. Site 119 mapping was flown in April 1988 to a scale of 1-inch = 200-ft with a contour interval of 5-ft. New mapping of the project area is required before the feasibility design can be completed.

11. GEOLOGY

a. Regional Geology.

i. Physiography. Pocahontas County is contained entirely within the Allegheny Ridges and Allegheny Plateau, both subdivisions of the physiographic province named Appalachian. The Allegheny Ridges sub-province includes the sharp-ridged mountains southeast of the Greenbrier River, and the Allegheny Plateau sub-province includes the low-angle or nearly horizontal rocks northwest of the ridges. The Greenbrier River is entirely within the latter.

ii. General Geology of Study Area. The surface or outcropping rocks of the Greenbrier River Basin within the area of interest include the lower portions of the Mississippian and upper portions of the Devonian Systems of Paleozoic age as follows:

Mississippian:
Greenbrier (Limestone) - Site 119 proposed quarry
Maccrady (Shales, Claystones, Siltstones)
Pocono (Shales, Sandstones, Claystones, Siltstones)*

Devonian:
Catskill(Shales, Sandstones, Claystones, Siltstones)*

*Present in abutments and/or valley floors at sites

The Greenbrier Series of the Mississippian, the topmost strata of study interest, contains up to about 600 feet of rocks that are predominantly calcareous. Limestone is the principal rock type. The limestone is quarried commercially. In the

vicinity of Marlinton, its best exposures are found in a belt two to three miles northwest of and roughly parallel to the Greenbrier River (see Exhibit No. 12, Regional Geologic Map). The proposed limestone quarry to be developed near Site 119 would produce stone from the Greenbrier Series.

The outcrop of the Maccrady Series of the Mississippian is found immediately beneath the Greenbrier Series. It is found in a very narrow belt, one to two miles northwest of the Greenbrier River, where it attains a maximum thickness of about 50 feet. Shale is the principal rock type.

The Pocono Series marks the basal major subdivision of the Mississippian. It outcrops in a one to two mile-wide belt immediately northwest of the Greenbrier River. The rock units present at Sites 110 and 119 are comprised of the Pocono Series and the underlying Catskill Series. The Pocono series consists of coarse, reddish-brown sandstones, often cross-bedded and conglomeratic, with brown, bluish-gray, and occasional red, sandy shales, claystones and siltstones. At other locations the Series contain some impure and lenticular coals, however no coals of any significance have been found at either study site.

The Catskill Series marks the top of the Devonian, and consists of a mass of red shales, claystones, and siltstones, interbedded with gray and brown micaceous sandstones. The valley floor and abutment bedrock at Site 119 is almost entirely comprised of Catskill Series rock.

iii. <u>Structural Geology</u>. A Regional Geology and Structural Map of the study area is presented as Exhibit No. 12. As shown on the map, the two major structural features in the area are the North Potomac (Georges Creek) Syncline, located in the northwest corner of the map, and the Browns Mountain Anticline, located in the southeast corner. Between the two prominent features, the bedrock strata dip to the northwest, forming a broad monocline. The dip is strongest in the south (6 to 8 degrees) near dam Site 110 and flattens to the north (1 to 2 degrees) near Site 119.

No evidence of major faulting was found in the study area. In the complex folded area comprising the Browns Mountain Anticline, disturbances were sufficient to produce some minor faults, but not of sufficient magnitude to be drawn on the geologic map. Evidence of a minor fault was found in the borings completed at the original Site 110 dam axis. Additional exploration will be required in later studies to determine the presence, orientation, and physical properties of any structural features at either site.

b. <u>Geology of Sites</u>. The bedrock in the vicinity of both sites consists of shales, sandstones, siltstones, and claystones, normally moderately hard, gray to reddish brown, and thin bedded.

The sandstones are primarily fine to very fine grained and thin bedded. The beds vary laterally and are somewhat difficult to correlate, but overall are comparable to many sedimentary beds of similar lithology throughout the Appalachian Plateau. No limestones or coals were encountered at either proposed dam axis. The bedrock is generally somewhat weathered from top of rock to about ten to twenty feet of depth. Due to the steepness of the topography and lack of reasonable access, no subsurface exploration was performed on the left abutment (looking downstream) at either site. Bedrock characteristics of these abutments are assumed comparable to those encountered in the right abutments.

i. Site 110. A geologic section depicting probable bedrock conditions at the site is included as Exhibit No. 15. Most of the drilling was completed at the original (upstream) dam axis, however it was later decided that topographic conditions were more favorable for dam construction about 1200 feet downstream, and the proposed axis was moved.

ii. Site 119. The geologic cross section for Site 119 is included as Exhibit No. 19. The bedrock lithologies are comparable to those encountered at Site 110, and are representative of the rock types described in the discussion of the Catskill Series. The overburden is generally no more than 10 feet thick along the abutments. The rock at Site 119 dips approximately 1 to 2 degrees (northwest), in comparison to the 6 to 8 degrees dip at Site 110.

c. Engineering Geology Considerations. No rock testing for the purpose of determining design parameters has been initiated to date. It is assumed, based on experience with similar rock units throughout the District, that the lithologies present in the abutments and valley bottom at both sites will provide suitable founding for the proposed roller compacted concrete dam.

d. Foundation Treatment. From five to twenty feet of weathered or otherwise unsuitable rock is expected to be removed from the abutments and valley floor at both sites. Since the area has been tectonically influenced by the same forces which created the Brown's Mountain Anticline and other structural features to the east, the possibility exists that minor inactive faults will be discovered during the excavation which will require additional treatment.

The multi-purpose dam at Site 119 will require a grout curtain to provide for positive cutoff of seepage around and beneath the structure. As a minimum, a two-line grout curtain, extending into the foundation approximately two thirds the height of the dam will be required throughout the foundation area. Additional lines will be required in the valley bottom, and in isolated areas of particularly high grout take. No water pressure testing

of the foundation has been performed to date, but is planned for future exploration.

e. Seismicity. All of Pocahontas County lies within the Deformed Appalachian Highlands seismotectonic region. Seventy-four earthquakes with epicentral intensities that exceed Modified Mercalli Intensity IV (MM IV) occurred in this region between 1844 and 1977 (MRM and Law, 1980). An additional fourteen earthquakes of equal magnitude occurred between 1977 and 1987 (U.S.G.S.). The largest earthquake was of epicentral intensity MM VII-VIII on May 31, 1897 at Giles County, Virginia. The Giles County Seismic Source is located approximately 70 miles (110 kilometers) southwest of Marlinton. An isoseismal map by Dockel (1970) shows that the Marlinton area would have experienced an intensity of MM V-VI from the May 1897 event. From several earthquake motion curves used in seismological studies conducted for the Huntington District (principally R.D. Bailey and Bluestone Dams), an MM V-VI felt-earthquake in the study area would produce a peak horizontal acceleration of between 0.06 and 0.09g, a peak horizontal velocity of about 6 to 8 cm/sec, and a duration of 1.5 to 2.5 seconds. ER 1110-2-1806 recommends a seismic coefficient of 0.10g for all concrete structures in Zone 2; consequently, 0.10g will be used in preliminary design considerations. Work done previously in a "Seismology Study of the Huntington District, Corps of Engineers" indicates that a quake of MM V-VI magnitude experienced at Marlinton has about a 60 percent probability of return within 50 years.

f. Future Exploration. Additional exploration will be required on both abutments of either site chosen for further study to develop geologic cross sections which meet the requirements of feasibility-level reporting. Site 110 will likely require more drilling since the majority of borings are now somewhat remote from the chosen axis. Both sites will require several borings along the left abutments, including some angle borings to determine the presence of faults, and to initiate studies on prevailing joint orientations. Due to the vertical and lateral variation among the beds, borings should be added on the right abutment of Site 119 to better facilitate correlation of rock units. At least a portion of the borings should be 4-inch diameter core or larger to provide samples for rock mechanics testing. All future holes drilled for either dam site will be pressure tested to allow for estimation of grouting efforts required. Additional holes may be considered necessary in the Site 119 borrow area to further define geologic conditions and to obtain samples for preliminary quality testing.

In addition, additional subsurface information may be required in order to evaluate haul road stability or any other fill embankments, cut-slopes, or structures which will require geotechnical input to design and construct.

12. CONSTRUCTION MATERIALS

a. General. Construction materials required for both sites consist of cement, fly ash, crushed stone for coarse aggregates, natural or manufactured sand for fine aggregate, and larger size stone for slope protection (riprap). Cement and fly ash will most likely be delivered to the site by trucks, but could also be partially transported by rail and then by trucks. The nearest known cement sources are located about 200 miles from the project. Fly ash is available from the power plants along the Kanawha and Ohio Rivers, with the closest known supplier being the John Amos plant near St. Albans, WV. Aggregate and riprap availability and requirements for each site are discussed below.

b. Coarse Aggregate Site 110. In accordance with ETL 1110-2-343 and EM 1110-2-2006 aggregates for RCC should meet the same standards of quality as required for conventional concrete. The rock material that will be obtained from the required foundation excavation at the site does not appear to be of suitable quality for use as coarse aggregate in the project concrete. The closest quarry currently operating is Seneca Quarries, Inc., located at Mill Point, WV, approximately 10 miles from Site 110. This operation mines the Greenbrier Limestone Formation and produces crushed limestone for coarse and fine aggregate.

Additional potential quarry sites are located from four to ten miles from the site. A dormant quarry capable of producing suitable aggregate, also owned by Seneca Quarries, exists on Price Run road, approximately 4-5 miles from Site 110. Because of proximity and suitable access, redevelopment or expansion of this quarry may be an economically feasible alternative for supplying coarse aggregate to the site. Another quarry, owned by the West Virginia Department of Highways (WVDOH), is located near the community of Edray. Stone from this quarry appears suitable for an RCC dam project, however, the operation has been dormant for several years. According to WVDOH representatives, the State might consider a Government purchase or lease of this property, but the locally available commercial sources would likely prove more economical. Additionally, it appears that new quarries (either Government or private) could be developed in the Greenbrier Limestone Formation at several locations in the vicinity of Marlinton if the dam construction creates a demand for aggregate.

c. Fine Aggregate Site 110. Fine aggregate for use in the project concrete may be either manufactured or natural sand. The quarries discussed above may not be capable of producing traditional gradations of manufactured sand in sufficient quantities because of unavailability of water for processing. However, a higher percentage of fines (passing #200 sieve) is desirable for RCC, which may allow the use of fine aggregate subjected to less processing. Natural sand is available but at

considerable distance from the site. Ready mix concrete plants in the area indicate that their sand sources are located in either Thomas, WV or New Castle, VA, approximately 80 to 90 miles from Marlinton.

d. Coarse Aggregate Site 119. The nearby hilltop borrow area has been designated as the source of coarse aggregate for Site 119. The required quantities are available here, and the rock appears to be of high quality. The quarry is located within the Greenbrier Limestone Formation. No laboratory testing has been initiated to date, but the Formation is a well known source of high quality aggregate in the region.

e. Fine Aggregate Site 119. A portion of the required fine aggregate for Site 119 could be obtained from a by-product of processing coarse aggregate in the hilltop borrow area. It is estimated that fifteen to twenty percent of rock processed to produce coarse aggregate is reduced to sand size; however, washing will likely be required to remove some of the dust. Conveying crushed stone to the staging area for processing, where water from the river is available, will be given consideration. If enough suitable manufactured sand cannot be produced, natural sand can be transported to the site from the sources discussed above for Site 110.

f. Riprap Requirements - Either Site. Riprap will likely be available for either site from the quarry chosen or developed to supply coarse aggregate.

13. HAZARDOUS, TOXIC and RADIOACTIVE WASTES

a. General. A cursory hazardous, toxic, and radioactive waste (HTRW) assessment was conducted by inspecting federal and state database information. This data provides an indication of potential and actual reported hazardous waste incidents on or adjacent to a particular site; the focus of this report is on the site, which is defined as the property on which the dam will be built at Site 119, and the study area which is defined as the watershed upstream of the site along the mainstem and major tributaries of the Greenbrier River. The criteria to be considered an area of concern for this assessment is based on HTRW likely to be encountered during construction at the site, and potential HTRW releases from upstream sources within the study area that could adversely impact the project. It is understood that complete Phase I Site Assessments will be required prior to real-estate acquisition in order to document prior land use, better establish ownership histories, and to physically inspect each individual property to be acquired.

Current land use at the site and within the study area is primarily residential pasture land with the exception of upstream

communities Cass, Frank, and Bartow, West Virginia. A former Chesapeake and Ohio (C&O) railroad embankment, abandoned in 1978, traverses the site and parallels the study area. Industries within the study area include a leather processing plant and a lumberyard.

The Toxic Release Inventory System (TRIS) which contains information on the industrial release and/or transfer of toxic chemicals as reportable under Title III of the Superfund Amendments Act of 1986, and the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) which is a compilation of known or suspected uncontrolled or abandoned hazardous waste sites, both listed Howe's Leather Company, located in Frank, West Virginia; several large industrial waste ponds surround the main plant (1973 and 1990 aerial photographs). Potential contaminants associated with leather processing include primarily ammonia, heavy metals, and sulfuric acid. This establishment has previously been investigated by the United States Environmental Protection Agency, but as of 16 November 1993 had not been added to the National Priorities List. The TRIS also identified another business, Judy Fencecraft Incorporated, a lumberyard in nearby Bartow which produces various wood products. Reported contaminants associated with wood preserving include various chromium, copper, and arsenic compounds. Again, these two companies are located on State Route 250 along the East Fork of the Greenbrier River nearly 20 miles upstream of the dam site.

Another reported liability within the study area was Murphy's Body Shop located on Deer Creek of the Greenbrier River in Boyer, West Virginia. This facility reportedly handles sufficient quantities (200-2200 lb per month) of hazardous waste to be considered a small quantity generator according to the Resource Conservation and Recovery Act (RCRA). Reported waste streams include RCRA wastes containing spent solvents possibly used in de-greasing. The West Virginia listing of underground storage tanks and leaking underground storage tanks reported no incidents at the site. This business is located northeast of Cass on State Route 28 approximately 15 miles upstream of the dam site.

b. <u>Summary</u>. The only environmental considerations existing at the dam Site 119 are related to the shallow soils immediately adjacent to the abandoned C&O railroad alignment. Potential contaminants include common herbicides and creosote. Since the railroad was abandoned, the former embankment was converted to a paved hiking trail and the rails, ballasts, and ties have subsequently been removed and replaced with new ballast, therefore any remediation required should be minimal. In regards to the study area, the three sites identified during the database search, in addition to limited sampling and testing along the abandoned railroad embankment, would require, at a minimum, adequate sampling and analyses to determine what impacts, if any,

past industrial waste releases have had on sediment and water quality.

14. RELOCATIONS

a. Highways and Roads. There are several West Virginia roads, in the upper reaches of both the dry dam and the multi-purpose dam impoundments, that are affected by flooding to the spillway crests. These roads are under the jurisdiction of the West Virginia Department of Highways (WVDOH) and are part of the Pocahontas County Numbered Route (PCNR) system. It is proposed that all West Virginia roads affected by the projects be abandoned without replacement within the Government Acquisition Line. All areas served by the roads to be abandoned will be acquired or have an alternative access. The alternate access to areas outside the Government Acquisition Line is from WVDOH-owned roads having acceptable grades. Abandonment of the roads could involve some increase travel distance for some of the surrounding residents, but that impact is considered minimal. There are no construction costs associated with abandonment of the roads, except for administrative costs. The costs of erecting barricades on abandoned roads at the Government Acquisition Line and removing existing bridges are not 02 Account costs and will be estimated as project costs. See Table 5 for a tabulation of the roads to be abandoned. The abandoned roads for both dry dam (4" and 5" flood control storage) alternatives are impacted equally.

Table 5 - Abandoned Roads

Road (PCNR)	Affected Length (mi)	
	Dry Dam	Multi-Purpose Dam
1	5.4	5.7
1/4	1.1	1.1
1/19	2.0	2.0
1/22	0.8	0.8
9	1.0	1.5
9/2	0.4	0.4
12	0.3	0.3
12/1	1.0	1.0
TOTAL	12.0	12.8

The United States Forest Service owns a road identified as USFS Route 1/8. This road connects with PCNR 1/4 and provides a secondary access to Seneca State Forest, Seneca Lake, and several rental cabins. Since USFS 1/8 is not the primary access to the area, this road will be abandoned without replacement. The length to be abandoned is about 0.6 miles for both impoundments.

Abandonment of the affected roads without replacement would create one isolated area along PCNR 1, generally between Clover Lick and Stony Bottom. In the absence of a more detailed study on road relocations and required supporting data, it is assumed for this report that acquisition of the isolated areas is less costly than providing alternate access. The issue of isolated areas will be investigated in more detail during preparation of the feasibility report.

b. Greenbrier River Trail.

i. General. The Greenbrier River Trail is a 75 mile-long recreational trail, designated for hiking, biking and horseback riding (non-motorized uses). The trail is located generally along the Greenbrier River through the study area. The trail was created from the abandoned C & O Railroad's single track railroad along the Greenbrier River. The trail was deeded to the West Virginia Railroad Maintenance Authority, an agency of the state of West Virginia, by quitclaim deed. It is assumed the state of West Virginia has a compensable interest in the trail.

ii. Flood Control Dry Dam. The trail relocation for Site 119 dry dam consist of approximately 3,000 feet of new trail that will be constructed on abandoned construction haul roads. The trail should begin on the right descending bank of the Greenbrier River at the existing trail, approximately 1,000 feet downstream of the dam, and end approximately 1,500 feet upstream of the dam on the right descending bank of the Greenbrier River at the existing trail. Aggregate paving will be provided for the entire length of the relocated trail. Rest areas will be provided randomly along the relocated trail. The remainder of the existing trail, upstream of the trail relocation and below the spillway crest elevation, will be subordinated to the Government's right to flood the trail in conjunction with the operation and use of the project.

iii. Multi-Purpose Wet Dam. The trail relocation for Site 119 multi-purpose dam involves constructing of approximately 11 miles of new trail, beginning on the left descending bank of the Greenbrier River, at the existing trail, approximately four miles downstream of the dam, and ending at the Stilington Bridge upstream of the dam. The bridge will be left in place for access to the existing trail on the right descending bank of the Greenbrier River. Aggregate paving (5-ft wide and 2-in thick) will be provided for the entire length of the relocated trail.

The relocation of the trail requires approximately 65 acres of clearing and 475,000 cubic yards of excavation and embankment. Portions of the trail alignment (approximately four miles) follow other trails, reducing the amount of clearing, excavation and embankment required. Preliminary topographic information indicates that the slopes along the relocated trail range from 4% to 20% with only a 3-mile portion of the trail exceeding 8% gradient. With a more detailed topographic mapping, the steeper parts of the trail can be designed to minimize the slopes. Rest areas will be provided randomly along the trail.

c. Utilities.

i. Monongahela Power Company. Monongahela Power Company owns, operates and maintains a three-phase transmission line which feeds the area from the north and crosses the proposed impoundments at two locations: about 1.1 miles upstream of Site 119 and in the vicinity of Clover Lick, about 5.1 miles upstream of the Site 119. The transmission line ends at a substation located along WV SR 28 at the mouth of Little Thorny Creek. ER 1110-2-4401, "Clearances for Power and Communication Lines Over Reservoirs," dated 5 September 1986, requires that certain minimum vertical clearances be maintained between a reference pool (spillway crest elevation) and the elevation of the low conductor. In the absence of more detailed information on the transmission line, it is assumed that both impoundments would require adjustment of the transmission line at both affected locations to ensure adequate vertical clearances. About 7,500 feet of the transmission line must be relocated for both impoundments.

There are single-phase power lines located within the lake area which will require adjustment or abandonment. These costs are considered minor, and the relocation of these facilities will not be further addressed until the feasibility report.

ii. Mountain State Telephone Company. Mountain State Telephone Company owns the local telephone service facilities in the area. These facilities consist of small, rural telephone service lines located generally along existing roads. No large telephone cables were observed in the area.

Some of the local telephone service lines located within the lake area will require adjustment or abandonment. These costs are considered minor, and the relocation of telephone facilities will not be further addressed until the feasibility report.

15. COST ESTIMATES

a. 5" Storage Dam Alternatives. The total project costs of the 5" flood control storage alternatives are approximately $80

Million for the Flood Control (Dry) Dam at Site 119 and $107.5 Million for the Multi-Purpose (Wet) Dam at Site 119. This represents benefit-to-cost ratios of approximately 0.8 and 0.6 respectively. The total project cost represents the cost associated with the project at the pre-feasibility level design. Cost data and summaries of accounts can be found in Addendum IIB and IIC of this appendix.

b. 4" Storage Dam Alternative. The total project cost of the 4" Storage Flood Control (Dry) Dam at Site 119, incorporating the innovative measures discussed in Section 8, is approximately $60.5 Million. This represents a benefit-to-cost ratio greater than 1.0. The total project cost represents the cost associated with the project at the pre-feasibility level design. Cost data and summaries of accounts can be found in Addendum IIA of this appendix.

16. CONCLUSIONS

The 4" Storage Flood Control (Dry) Dam at Site 119 which incorporates the innovative measures has a benefit-to-cost ratio greater than 1.0. This alternative illustrates that a Federal interest has been identified and therefore, a more detailed feasibility phase is recommended for the Greenbrier River Basin. This feasibility study will produce detailed designs and costs resulting in the selection of the National Economic Development (NED) Plan. The innovative measures applied to the 4" flood control storage alternative in this Evaluation Study will also be applied to all flood control storage alternatives investigated during the feasibility phase.

Engineering features during the feasibility phase will be designed to the level necessary to develop the baseline design of the NED Plan. Various dam alternatives will be investigated at Site 119 so that the NED plan can be identified. No further investigations will be performed at Site 110 due to the analysis in this report. Engineering investigations during the feasibility phase will include:

- Design of all alternatives to the feasibility level of design with a Total Project Cost Estimate for each and a Baseline Cost Estimate for the NED plan.

- Establishment of all technical design criteria and functional operation requirements of the Government and the sponsor.

- Hydrologic and hydraulic studies required to determine the functional design requirements of the project.

- Mapping the pool and areas that may be used for site access and borrow/spoil area.

- Subsurface exploration and geotechnical analysis required to support the foundation design and structure type.

- HTRW Phase I site assessments and Phase II investigations if necessary.

- Relocation studies including utilities, trail, and roads.

- Determination of suitable sources of construction materials.

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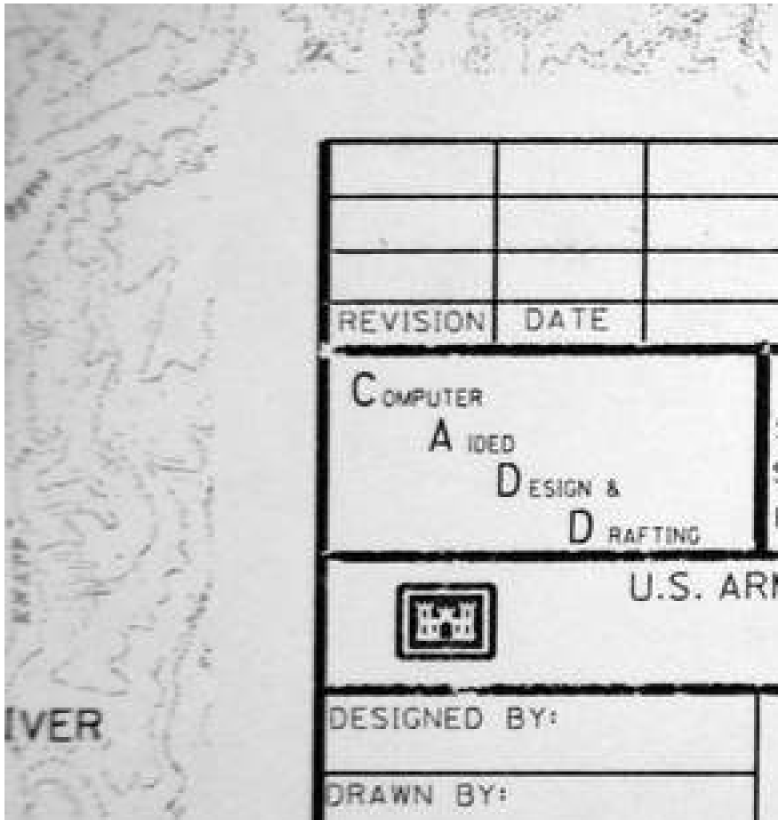

REVISION	DATE	DESCRIPTION	BY

COMPUTER AIDED DESIGN & DRAFTING

CADD COMPUTER INFORMATION

SYSTEM: INTERGRAPH CADD SYSTEM

SOFTWARE: IGDS VERSION 8.8

FILE SPEC: s7007e:/usr4/nrg/fsd/eddc/gb110dry.dgn

U.S. ARMY ENGINEER DISTRICT, HUNTINGTON
CORPS OF ENGINEERS
HUNTINGTON, W.VA.

DESIGNED BY:

DRAWN BY:

CHECKED BY:

SUBMITTED BY:

CHIEF,DESIGN BRANCH

GREENBRIER RIVER BASIN, WEST VIRGINIA
GREENBRIER DAM
SITE 110 & 119
OVERALL SITE PLAN
DRY DAMS – 5” STORAGE

APPROVAL RECOMENDED:

CHIEF,ENG DIVISION

APPROVED: DATE:

COL. C. E. DISTRICT ENGINEER :

APPROVED FOR:

DATE:

SCALE: N.T.S.

CONTR.NO:

DRAWING NUMBER

SHEET OF

EXHIBIT NO. 1

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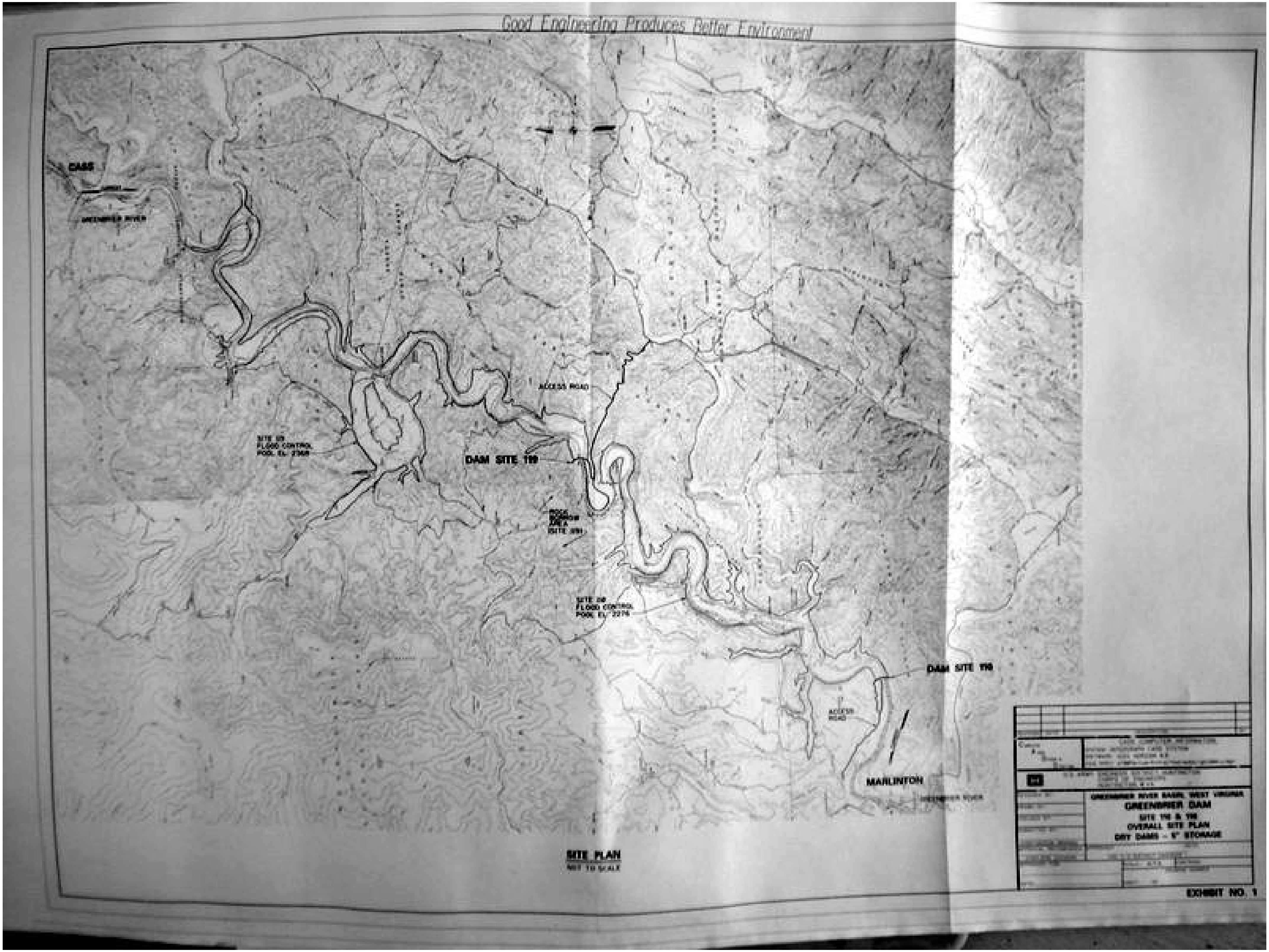

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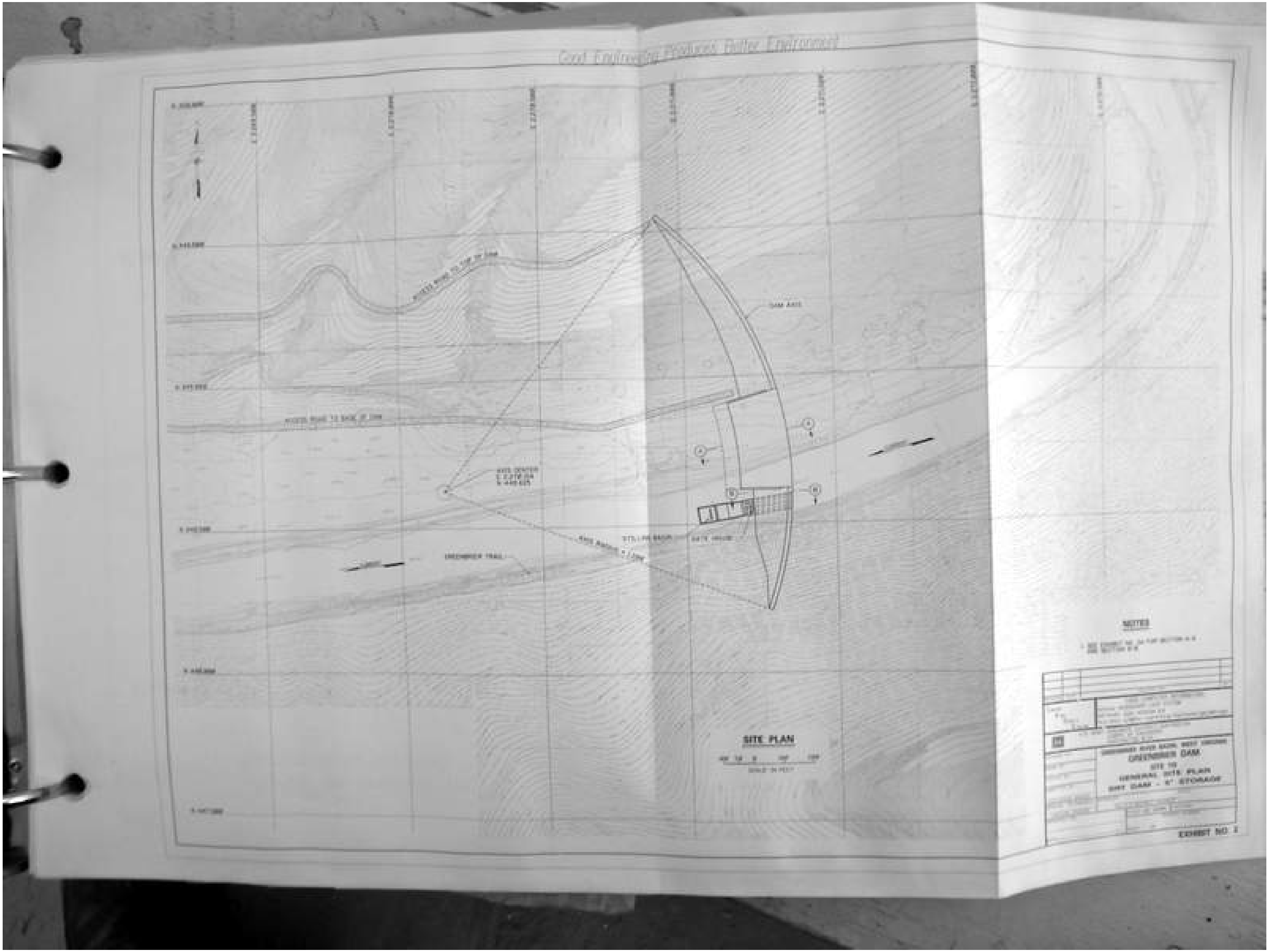

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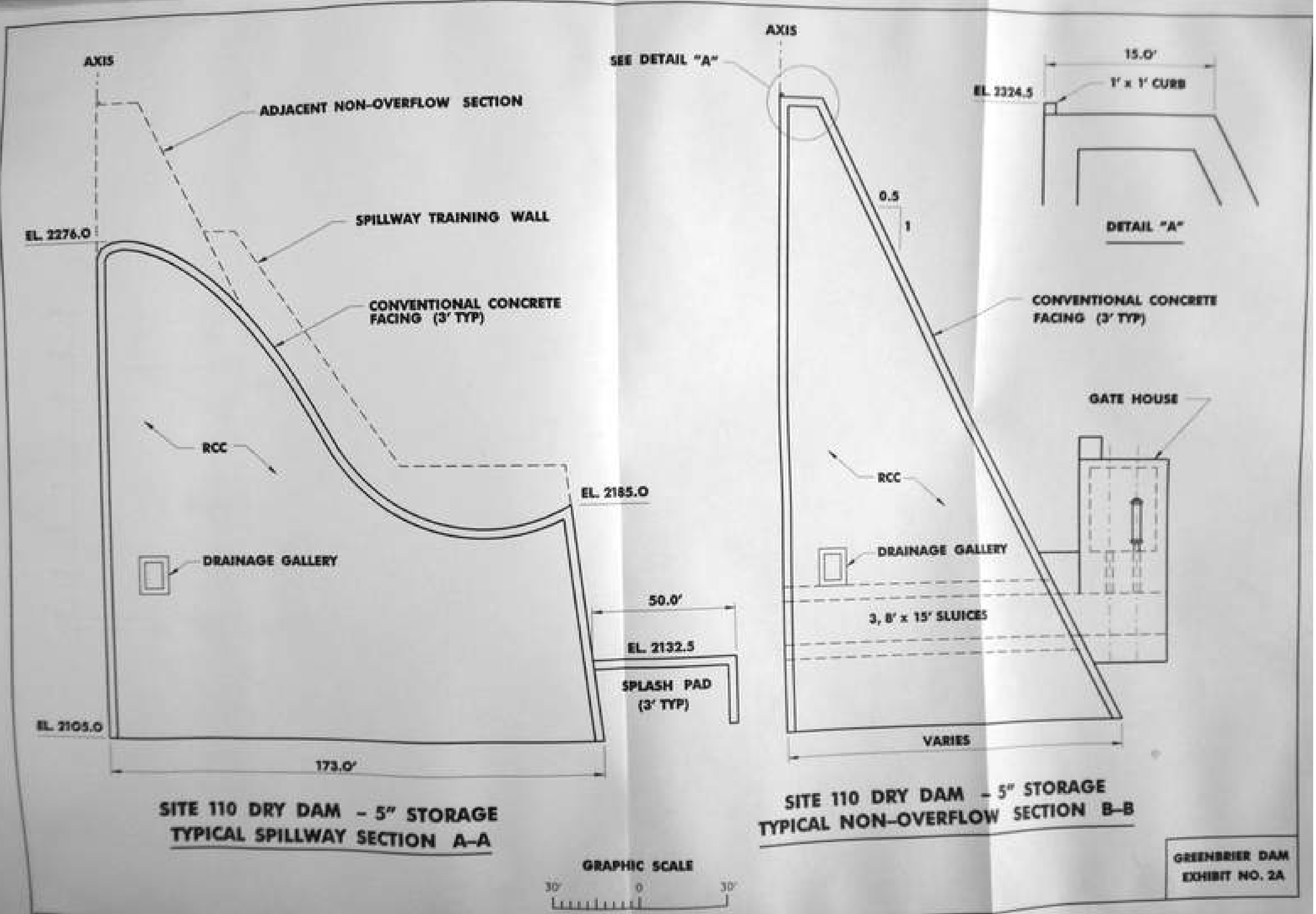

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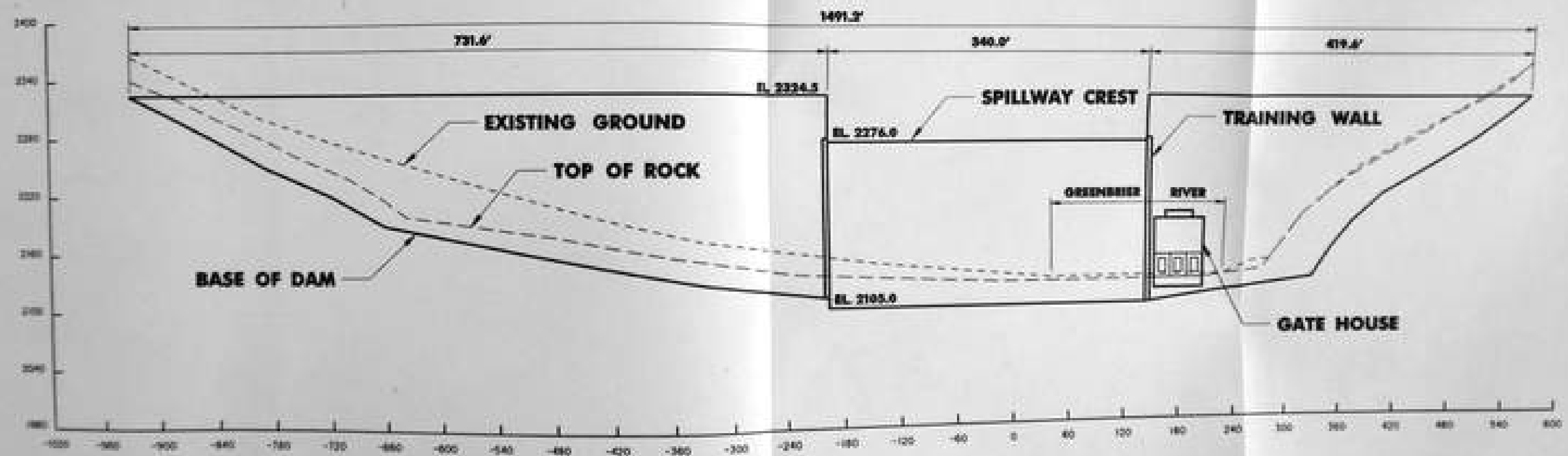

SITE 110 DRY DAM – 5" STORAGE
DEVELOPED PROFILE ALONG AXIS
(LOOKING UPSTREAM)

GRAPHIC SCALE

120' 0 120'

GREENBRIER DAM
EXHIBIT NO. 2B

GREENBRIER RIVER

1. INTRODUCTION

This Addendum presents the results of the hydrologic and hydraulic studies and computations involved in the preliminary design of the flood control dams for the Greenbrier River Basin Study. Two dam sites, designated Sites 110 and 119, were investigated during this phase of study. Site 110 is located approximately 2 miles upstream of Marlinton, WV; while Site 119 is located approximately 11 miles upstream of Marlinton. For this study only a dry dam was evaluated at Site 110 while both a wet and dry dam were evaluated at Site 119. The initial phase of the study was a screening process to determine which site was most economical for a dry dam. This screening process showed that Site 119 was more favorable. Therefore, a wet and dry project was evaluated in more detail at Site 119. As the more detailed evaluation was only completed for Site 119, this Addendum will present the hydrologic and hydraulic studies for this site only. The hydrologic and hydraulic studies were completed to a sufficient level of detail to determine if there is a Federal interest in developing the project to a feasibility level design. Therefore, some segments of the study are only at a reconnaissance level of detail while other segments are near feasibility level.

2. AREA DESCRIPTION

The Greenbrier River, carrying the greater part of Pocahontas County's runoff, has its source in two forks originating in the extreme northern end of the county. East Fork flows in a southwest direction to join the West Fork at Durbin, WV where it forms the mainstem of the Greenbrier River. The river then flows in a comparatively straight line in a southwest direction across Pocahontas and Greenbrier Counties to a point south of Lewisburg, WV where it turns westward to form a portion of the Greenbrier-Monroe County line. It then enters Summers County and after much meandering joins the New River at Bellepoint, WV, one and one half miles south of Hinton, WV. The drainage area at the mouth of the Greenbrier River is approximately 1641.0 sq. miles. From the headwaters above Durbin to its confluence with the New River at Hinton, the river falls 800 feet in 167 miles. Exhibit No. 1 is a basin map of the Greenbrier River.

3. CLIMATOLOGY

a. General Characteristics. The Greenbrier River Basin lies in the temperate zone and experiences the usual seasonal variations in temperature. The basin is affected by frontal air-mass activity, and is subjected to both continental polar and maritime tropical air masses. Frequent and rapid changes in the weather

occur due to the ... The prevailing wind direction is from the
pressure areas. The prevailing wind direction is from the southwest.

b. Meteorological Records. Meteorological data for the basin is available at a few stations within the basin and from numerous stations immediately adjacent to the basin. The station locations, elevations, and the 30-year normals are given in Table No. 1.

c. Temperature. The period of record of temperatures within the basin extends from 1888 to date. Temperatures recorded at Marlinton have varied from a minimum of -27 degrees to a maximum of 100 degrees. The mean annual temperature for the region is about 55 degrees. The growing season averages about five months. The normal temperatures for individual stations, where available, are listed in Table No. 1. A monthly summary for representative stations are listed in Table No. 2.

d. Precipitation. The normal annual precipitation over the basin is approximately 44 inches and is listed for individual stations, where available in Table No. 1. Average monthly and annual precipitation are also listed for four stations in Table No. 3. The basin lies south of the most frequented path of extensive meteorological disturbances which, in winter and spring travel from southwest to northeast, converging toward the St. Lawrence Valley. Summer rains usually result from conventional or orographic origin. They are usually confined to relatively small areas and are of short duration and high intensity. The summer-type storms usually occur during June, July, and August.

Precipitation in the late fall, winter, and early spring is characterized by less intense rainfall of extended duration and large areal extent, often affecting several states. Occasional stagnation and stationary development produces prolonged precipitation.

4. RUNOFF AND STREAMFLOW DATA

a. Runoff Characteristics. The rolling to rugged hills of the Greenbrier River Basin and the moderately steep profiles of the streams cause comparatively high peak discharges and short flood durations. Basin runoff is highest during the winter months when storm rainfall may be augmented by melted snow, and when frozen or saturated ground results in low infiltration rates. The runoff is lowest during the late summer and early fall when the ground is dry and infiltration rates are high. Table No. 4 presents monthly and annual runoff for the Buckeye gaging station.

b. Streamflow Records. Information relative to past flooding in the area has been derived from gaging records of three gages in the general vicinity of Marlinton and from historical high watermarks. Although two of these gages no longer exist, records

obtained from all gages were utilized in the preparation of this report. The existing Buckeye U.S.G.S. gage is located 3.5 miles downstream from the mouth of Knapp Creek at Greenbrier River mile 105.7. This gage was established in 1929 and consisted of a chain gage attached to a highway bridge. In February 1939, this gage was replaced with a water-stage recorder which is presently being used. Pertinent data concerning the Buckeye gaging station is given in Table No. 5. Since this station has been rated by discharge measurements of moderately high stages only, it was necessary to extend the rating curves for studies of major floods.

c. Water Losses. Rainfall and streamflow data indicate that infiltration losses may approach zero during severe winter-type storms, and may be as low as .05 inches per hour during exceptional summer-type storms.

d. Obstructions to Streamflow. Natural flow conditions along the Greenbrier River have been impaired by manmade structures which constrict the stream channel and adjacent flood plains. The manmade constrictions, natural obstructions, and debris accumulation combine to produce high stages and strong currents which tend to increase damage. Should floods reoccur having the magnitude of historical floods, the heights of water would be increased under present day conditions.

5. STORMS AND FLOODS OF RECORD

a. Historical. Several severe Greenbrier River floods have been experienced in the Marlinton area since its settlement. Some of these larger floods occurred in the 1800's and few, if any, records are available to indicate their exact size.

The highest known floods, which occurred in 1812, November 1877 and November 1985, were caused principally by the Greenbrier River. Two damaging floods occurred in March and July 1954 and were caused by high flows from both the Greenbrier River and Knapp Creek. The greatest rainfall for the 1985 flood occurred over Knapp Creek, but the total basin above Buckeye received an average of 8.0 inches.

A flood of the magnitude that occurred in 1877 would, if now repeated, cover practically the entire community of Marlinton, WV. This flood was reportedly six to seven feet higher than the floods of 1954.

The 5 November 1985 flood is regarded as the largest flood that has occurred during the period of record. Older residents believe that this flood was at least nine feet higher than that which occurred in 1913. However, historians indicate that the November 1877 flood was an extremely large flood in the area and refer to it as the "Flood of Floods." Table No. 5 shows the maximum gage heights and maximum discharge for the November 1985 storm at several locations within the Greenbrier river basin.

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TABLE No. 5

STREAMFLOW STATIONS IN THE GREENBRIER RIVER BASIN

Location	Miles Above Mouth	Drainage Area (Sq. Miles)	Agency	Period of Record	Maximum Gage Height Feet (1)	Type of Gage	Discharge in c.f.s Max.(1)	Min.	Mean
Greenbrier River at Durbin	153.4	133	USGS	1943-Present	15.82	WS	37,700	0.0	258
Greenbrier River at Buckeye	105.6	540	USGS	1929-Present	23.20	WS	80,000	3.8	875
Greenbrier River at Alderson	29.2	1,364	USGS	1895-Present	23.95	WS	90,000	24	1,994
Greenbrier River at Hillsdale	5.5	1,619	USGS	1936-Present	25.68	WS	82,000	39	2,255

WS- Water Stage recording gage
Maximum Discharges From U.S. Geological Survey
Open File Report 86-486

(1) Figures for the 5 November 1985 flood.

b. General. Floods are not limited to any month, although winter and spring floods are more frequent. Summer-type storms have occurred over the basin, producing local floods without affecting adjacent areas. The hilly topography of the basin is conducive to rapid concentration of runoff. This results in high peak floods of short duration.

c. Flood Descriptions. The following are brief descriptions of known large floods that have occurred in the Marlinton area. These descriptions are based upon information obtained from field investigations after floods, from interviews of local residents and from articles appearing in the "Pocahontas Times," a weekly newspaper published in Marlinton since 1882. Excerpts from other newspapers are also included.

THE POCAHONTAS TIMES, 11 FEBRUARY 1932

At Marlinton, Squire S.L. Brown reports the rainfall in ten hours as 3 inches. At Marlinton the river rose 13 feet and better. It was the highest since 1918. Knapp Creek got big too, but not as high as the river. This flood in the Greenbrier was remarkable in that it came up so quickly and went down almost as fast. The crest of the flood at Marlinton came in the afternoon, rising three or four feet an hour. The water broke over the banks and came into houses on the lower ground, with little time for warning.

HUNTINGTON HERALD DISPATCH, 21 JANUARY 1937

At Marlinton, the Greenbrier spilled over its banks at the junction with Knapp Creek. Streets of the mountain city were flooded around the railroad station.

CHARLESTON GAZETTE, 22 FEBRUARY 1953

One person was killed and another feared dead as the Greenbrier and the New River went on a rampage today and inundated an 80-mile stretch on the state's eastern border from Marlinton, Pocahontas County, to Hinton in what is believed to be the area's worst flood in 15 years. Early reports from Marlinton said the Greenbrier River hit its highest level since 1930. After reaching its crest however, the river began falling nearly 6 inches per hour at Marlinton about 6 P.M.

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THE POCAHONTAS TIMES, 26 FEBRUARY 1953

Last Saturday was flood day on the Greenbrier. After twenty-four hours of rain, the Greenbrier and Knapp Creek came down with about the biggest freshet in twenty years. At Marlinton the river was fourteen feet and at Buckeye about a foot more. The creek was a little higher than the river, in proportion. I figure this is about the highest water since March 1913. Some damage and much inconvenience was caused by flooding of basements, damaging furnaces, stokers and what all. This was a flash flood and the first hour the water just boiled up.

THE POCAHONTAS TIMES, 4 MARCH 1954

Sunday afternoon it came on to rain and how it did pour down for about thirteen hours. Then the wind changed and how it did snow for several hours; to pile up 6 inches on the high tops and three inches on the river. Our rainfall amounted to 2-1/2 inches.

Stream flushed up strong. There was water in the basement of the grade school and in some basements of residences. There was no school on Monday. The swinging walk bridge over Knapp Creek was washed out by the flood.

THE POCAHONTAS TIMES, 22 JULY 1954

On Wednesday night, July 14, there was continuous lightening for 12 or so hours with plenty of thunder, wind, rain, and hail. The rain was a cloudburst in places. Rain fell continuously for nearly ten hours. A gage registered six inches.

Knapp Creek was higher at Marlinton that at any time since 1913. East of the railroad many basements were flooded. The road between Marlinton and Huntersville was blocked by deep water for many hours. Some people from Knapp Creek and Greenbrier went home by way of Clover Lick and Cass. Fortunately for Marlinton, Greenbrier River stayed within reasonable bounds--some six or eight feet under flood stage. Stony Creek really was high; Marlin and Price Runs higher than in memory of any old timer.

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THE POCAHONTAS TIMES, 9 MARCH 1967

Heavy rains and melting snow sent the creeks and rivers on a rampage Monday night and Tuesday morning. They rose fast Monday night and still it rained hard. In Marlinton the fire alarm sounded about 1:45 A.M. and people were awakened and warned and many were taken out in truck or boat. Riverside was covered. Telephone service was out because the equipment was under water. The Power Company had heavy losses.

In Marlinton, the water came through from above the tannery and all along the river. Knapp Creek came over at the dam. Water came down runs, off the hills, every place. Second, Third and Fourth Avenues had up to four feet of water in places. First Avenue had 7 or 8 feet.

All those we could find who remembered the flood of 1913 thought that this one was at least two feet higher. Richard McCarty said the flood of all floods was in 1877 but nobody can compare this with it. But this was the most water anyone remembers and it will take a lot of drying out.

THE POCAHONTAS TIMES, 16 MARCH 1967

Marlinton was pretty much in a state of shock as the realization came that we had a flood such as you read about and it is almost impossible to realize the amount of damage water can cause.

A million and a half dollars seem to be the best guess. There was a tremendous loss to businesses, as well as homes.

Dever's Store and the A&P were particularly hard hit with damages running $60,000 to $75,000 each. The hospital estimates their damages at $60,000. The Board of Education estimates their losses about $100,000. Lots of goods were damaged at Royal Drug Store, S. B. Wallace, Western Auto, Galford's, Williamson Supply, and C.J.Richardson's Hardware Store.

THE POCAHONTAS TIMES, 4 FEBRUARY 1971

Don't miss seeing the ice on the Greenbrier. A little bit of all kinds of weather, mostly cold. However, Friday night the temperature quickly rose to the 40's and we had a downpour of rain, plus

lightning and thunder. The rain raised the river and broke the ice, moving it Saturday afternoon part of the way. It jammed above Seebert and backed up to the Buckeye. The rainfall and snowfall for January were 4.01 inches and 14.1 inches respectively in the Marlinton area.

THE POCAHONTAS TIMES, 3 JANUARY 1974
1974 FLOOD

A flood the day after Christmas (Note: 1973) surprised the County. Heavy rains Christmas night with melting snow quickly brought water rushing down all the hillsides and streams. Knapp Creek was thought to have had more water than for many years. It blocked 39 in many places and was soon over the dam at Marlinton. The run from Thomas Town was booming and the east side of Marlinton suffered. Especially hard hit were the service stations, stores and offices in the Post Office block. Also Stony Creek broke over and flooded Riverside and down through Burns Motor Freight. The A&P had 4 inches of water.

THE POCAHONTAS TIMES, 6 JUNE 1974

After several days of rain and 2 1/4 inches measured between 8 a.m. Saturday and 8 a.m. Sunday, Greenbrier River rose rapidly Sunday to about 11 ft. 3 in. at Marlinton and 14.55 feet at Buckeye. Flood stage at Marlinton is about 10 feet, when it comes into First Avenue; at 11 feet it comes through the storm drains into Main Street.

THE POCAHONTAS TIMES, 14 OCTOBER 1976
1976 FLOOD

The rains came and the river rose.

Friday night at 11:03 the automatic flood alarm system sounded in the Marlinton Fire Department office, which indicates from upper drainage areas that a 10 foot level of water will 4 hours later be at the Marlinton bridge. Twenty-four hours later (after 11 p.m. Saturday), the alarm reset itself when the water level went below flood stage, after reaching a crest of 13.1 feet at Marlinton and 16.55 feet at Buckeye about 3 p.m. This system enabled the Fire Department to chart within a few inches the time and actual level of the water, being in constant

communication with Cincinnati and other information centers.

THE POCAHONTAS TIMES, 7 NOVEMBER 1985
THE FLOOD OF 85: NEWSPAPER ACCOUNTS

Details on the storm that caused the widespread flooding are sketchy at this time. Rain gauges in the Marlinton area showed a total of around 7 to 7 1/2 inches of rain over the weekend and on Monday. As the rain in Marlinton didn't seem sufficient to cause such massive flooding, it is assumed there must have been heavier rains in the more northern sections of the County.

Information available to the National Weather Service also didn't predict a flood of the magnitude that occurred. For most of Monday the NWS was predicting that the water in Marlinton would crest at 14 feet, which would have been about a foot higher than the 1967 flood crest. Later the prediction was changed to an 18 foot crest, but by that time the information was too late to do anyone any good.

As best as can be figured now, the crest in the river at Marlinton was 21.8 feet. Buckeye was about 24.5 feet. After holding at the same level the water began to recede about 2:30 a.m. Tuesday. Before dark Tuesday, the river and creek were back in their normal channels.

6. UNIT HYDROGRAPH COMPUTATIONS

Since no discharge records are available at Marlinton, it was necessary to transfer a unit hydrograph from the Buckeye, U.S.G.S. gage, located a few miles downstream from Marlinton, using methods set forth in EM 1110-2-1405. A unit hydrograph was derived at Buckeye from the flood that occurred on 5 November 1985 from a direct analysis of rainfall and runoff. A base unit hydrograph, shown on Exhibit No. 2 was developed from the storm that occurred on 5 November 1985. This unit hydrograph was then transferred to various locations at Marlinton, including Knapp Creek at the mouth. The resulting unit hydrographs for the Greenbrier River at Buckeye, Greenbrier River above Durbin, and Knapp Creek at the mouth are shown on Exhibit Nos. 2, 3, and 4, respectively.

7. STANDARD PROJECT FLOOD

The Standard Project Flood was computed in accordance with Civil Engineering Bulletin 52-8, EM 1100-2-1411, dated March 1952 (Revised March 1965), titled "Standard Project Flood Determination."

surface profiles on the Greenbrier River was 0.04 for the main channel and varied from 0.05 to 0.065 for the overbanks, and on Knapp Creek varied from 0.045 to 0.05 for the main channel and from 0.055 to 0.08 for the overbanks.

The coefficients of contraction and expansion used were 0.1 and 0.3 for the valley sections, and 0.2 and 0.4 for the bridge sections, respectively.

The existing water surface profiles were developed using 47 cross-sections and 1 bridge section in the Marlinton reach. The overbank portions of the cross-sections were obtained primarily from topographic maps (2-foot contour intervals) based on aerial photography and field surveys obtained during 1981. Stream soundings were obtained at 30 locations by field surveys in order to establish the channel portion of the cross-sections below the water surface shown on the mapping.

In the Alderson reach, the existing water surface profiles were developed using 13 cross-sections and 2 bridge sections.

The special bridge option in the HEC-2 program was used to determine the bridge losses at the bridges in the study areas. This option computes pressure flow through the bridge and weir flow over the bridge and approach roadways on the floodplain when the tailwater elevation exceeds the low chord elevation on the bridge.

b. Modified Conditions with Proposed Reservoir Sites Above Marlinton. The proposed plan which offers the greatest flood reduction for the City of Marlinton and other downstream communities, consists of a reservoir located on the Greenbrier River at river mile 119.

Modified profiles were computed for the Marlinton reach assuming 2, 4, and 6 inches of flood control storage in reservoir site 119. Flows were routed through the reservoir and a correlation curve developed at each damage point to estimate the modified flows. These reduced flows were then used in the HEC-2 program to produce modified profiles where data was available.

The modified flood frequency profiles for the Marlinton reach depicting 2, 4, and 6 inches of flood control storage in reservoir site 119 are shown on Exhibit Nos. 12, 13, and 14.

11. RESERVOIR STORAGE

a. Reservoir Area and Capacity Data. The area and capacity computations for site 119 were based upon data obtained by planimetering USGS quadrangle sheets with a scale of 1 inch equals 2000 feet and using 40-foot contour intervals. The area and capacity were computed simultaneously by means of a computer

program using curvilinear interpolation. The program computes volumes by one foot increments using the average end-area method. A tabulation of reservoir area and capacity is given in Exhibit No. 15.

b. <u>Minimum Pool (Wet Dam) Storage Requirements</u>. Minimum pool requirements for a multiple-purpose project at Site 119 were selected based on provision of adequate storage for sediment and downstream releases while constraining drawdown to avoid significant adverse effects on lake recreation.

The project life (period of analysis) is 100 years, and sediment accumulation at Site 119 for this period is estimated to require 0.5 inch of storage. As the water volume of the minimum pool diminishes over time, fish entrainment through the outlet works creates an undesirable situation which can be avoided with an increase in storage. An additional 0.5 inch of storage is included to maintain suitable conditions for aquatic life in the lake as sediment accumulates during the project life. Thus, the selected minimum winter pool is 1.0 inch of storage, elevation 2302 ft.

With a multiple-purpose reservoir, the inundation of several miles of the river is regarded as an unavoidable environmental loss. One of the major effects would be loss of 10-12 miles of stream fishing which is a superior resource of the region and the state. As an offset, the formulation of the reservoir can be adjusted so that reservoir releases are managed to improve biological productivity of the Greenbrier River downstream of Site 119. For this study, several reservoir storage and operational options were evaluated to consider release options verses drawdown effects on lake recreation. Given the favorable land-water relationships of Site 119, it was decided that high quality recreation facilities could be designed to accommodate drawdown.

For this phase of the study, a summer conservation pool at elevation 2349 ft., with 3.77 inches of storage, was chosen as an appropriate reservoir size for addressing the outlined concerns. Sufficient water can be released for downstream needs, even during droughts, while avoiding significant adverse effects at the lake. With a dependable release during fall drawdown equivalent to 1.0 inch of runoff, the desirable outflow pattern is continued during the fall season. Thus, the initial winter conservation pool would be in a range between elevation 2336 ft. to elevation 2302 ft. dependent upon drought conditions. There would be a return to the maximum winter conservation pool at elevation 2336 ft. as flow conditions allow.

The dependable improved outflow increases downstream productivity, and significant adverse effects on lake recreation due to drawdown are avoided. A smaller plan would not achieve this balanced effect.

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c. Flood Control Storage Requirements.

i. Determination of Required Flood Control Storage. Determination of the flood control storage requirements was based upon an economic analysis of 2-, 4-, and 6-inches of net flood control storage. Based upon this analysis, a project with slightly less than 5 inches of flood control storage was the NED plan. However, further analysis showed that approximately 5-inches of flood control storage would be required to prevent a significant percentage of the downstream damages associated with a reoccurrence of the November 1985 flood. Therefore, the initial phase of this evaluation concentrated on a reservoir with 5-inches of flood control storage. However, as discussed in the main report, an economic analysis showed that this plan had a benefit to cost ratio of less than unity. Based upon this determination a dry dam with 4-inches of flood control storage was also analyzed.

ii. Plan of Reservoir Regulation for Flood Control. Releases from Greenbrier Reservoir would be governed by stages on the Greenbrier, New, Kanawha and Ohio Rivers and by the existence and operation of other flood control projects in the comprehensive Ohio River Basin flood control plan. Efficient operation of the reservoir will require a regulated outflow. During periods of high stages on Greenbrier, New, Kanawha and Ohio Rivers, it may be necessary to store all inflow to the reservoir, while during falling stages downstream, it will often be desirable to release storage at a bankfull rate below the dam in order to empty the reservoir as rapidly as possible. It will also be desirable, at times, when there is no flood threat downstream, to pass minor floods up to full channel capacity below the dam. However, no detailed plan of regulation was developed for this study. It was assumed, for the purpose of development of downstream flood reductions, that during flood control operations the outflow from the project would be limited to 10,000 cfs (channel capacity) until flood control pool was reached.

d. Storage Allocations. The storage allocations selected for use at the proposed reservoir site 119 are provided in Table No. 10.

e. Siltation. Most of the area above the Greenbrier dam site is wooded. Only a small portion of the area is cultivated or cleared for farming. In the past, the stream has not appeared to carry a heavy silt load; however, no actual samples have been taken to determine the amount of sediment carried. For this study, a siltation rate of 0.25 acre-feet per square mile of controlled drainage area per year appears to be a representative value for the reservoir. This rate was determined by analyzing the measured siltation rates for reservoirs in the Big Sandy Basin. Based on this rate of siltation, the required sediment storage to provide a reservoir life of 100 years is 9,300 acre-ft, which is equivalent to 0.5 inches of runoff.

TABLE No. 10

GREENBRIER LAKE SITE 119 STORAGE ALLOCATIONS

Project	Elevations	Incremental Capacity	Inches of storage	Allocations
Wet	2223.0-2302.0	18,400 Ac.ft.	1.0	Sediment Storage/ Aquatic Life
	2302.0-2336.0	32,100 Ac.ft.	1.77	Min. Flow/ Mitigation
	2336.0-2349.0	17,900 Ac.ft.	1.0	Seasonal Rec.
(Sum)	2349.0-2388.0	73,600 Ac.ft.	4.0	Flood Cont.
(Win)	2336.0-2388.0	91,200 Ac.ft.	5.0	Flood Cont.
Dry (5-in)	2223.0-2284.0	9,300 Ac.ft.	0.5	Sed. Stor.
	2284.0-2368.0	91,200 Ac.ft.	5.0	Flood Cont.
(4-in)	2223.0-2284.0	9,300 Ac.ft.	0.5	Sed. Stor.
	2284.0-2358.0	82,100 Ac.ft.	4.0	Flood Cont.

12. SPILLWAY

a. General. An uncontrolled emergency spillway will be provided for both the wet and the dry dams with the crest located at the top of the flood control pool. The spillways are designed to pass the Probable Maximum Flood (PMF) without using the outlet works. The spillways will have vertical upstream faces with the upstream and downstream quadrants shaped in accordance with Engineer Manual 1110-2-1603, "Hydraulic Design of Spillways", dated 16 January 1990. Determination of the quadrant shapes was made using the "CORPS" program H1108, "Crest and Upper Nappe Profiles for Elliptical Crest Spillways". The discharge ratings for the spillways were determined using the "CORPS" program H1107, "Stage-Discharge Relation for Elliptical Crest Spillway".

b. Determination of Maximum Spillway Width. The determination of the spillway width and the calculation of the top of the dam for both the wet and dry dams at site 119 are dependent upon a requirement that the peak outflow from the project should not exceed the peak discharge of the natural storm hydrograph. This requirement insures that the project does not create greater downstream damage during a PMF event than what would occur under natural conditions. The width of the spillway is adjusted so that the peak discharge of the natural hydrograph is not exceeded when the storm hydrograph that exists under project conditions is routed through the reservoir. Since the outflow from the reservoir is dependent upon the spillway capacity, the spillway width determines the peak pool elevation and thus the top of dam elevation.

The difference between the 'D' hydrograph (natural) and the 'A' hydrograph (with project) reflects the change in basin hydrology between pre and post project conditions. Since these two hydrographs were derived under similar assumptions, it is the position of CEORH-ED-H that they are the most comparable with regard to limiting the peak outflow from the project below the peak discharge that would have occurred under natural conditions. Therefore, for the current study, a trial and error process was completed of assuming a spillway width and designing the spillway for the head associated with the routing of the 'C' hydrograph ('A' Hydrograph precipitation increased by 50%). The acceptability of the assumed spillway width was determined by routing the 'A' hydrograph through the spillway, based upon the 'C' hydrograph design, and then verifying that the peak discharge from the 'A' hydrograph (with project) routing was less than the peak discharge of the 'D' hydrograph (natural). Using this criteria, the maximum spillway width at site 119 was determined to be 440 feet for the wet dam, 345 feet for the 5.0-inch flood control storage dry dam (5-inch dry dam) and 310 feet for the 4.0-inch flood control storage dry dam (4-inch dry dam).

c. Spillway for the Wet Dam. The dam would have an ungated, 440-foot-wide ogee spillway with a crest elevation of 2388.0 ft., NGVD to provide a flood control storage volume of 91,200 acre-feet or 5-inches of runoff in the winter and 73,600 acre-feet or 4-inches of runoff in the summer. The spillway crest was underdesigned using a design head of 27.0 feet which provides an H_e/H_d ratio of 1.33 which is in accordance with EM 1110-2-1603. Exhibit Nos. 16 and 17, provide the output from programs H1107 and H1108, respectively. Exhibit No. 18 provides the discharge rating curve for the spillway.

d. Spillway for the Dry Dams. The 5.0-inch dry dam would have an ungated, 345-foot-wide ogee spillway with a crest elevation at 2368.0 ft., NGVD to provide a flood control storage volume of 91,200 acre-feet. The spillway crest was underdesigned using a design head of 31.8 feet which provides an H_e/H_d ratio of 1.33 which is in accordance with EM 1110-2-1603. Exhibit Nos. 19 and 20,

provide the output from programs H1107 and H1108, respectively. While Exhibit No. 21 provides the discharge rating curve for the spillway.

The 4.0-inch dry dam would have an ungated, 310-foot-wide ogee spillway with a crest elevation at 2358.0 ft., NGVD to provide a flood control storage volume of 82,100 acre-feet. The spillway crest was underdesigned using a design head of 34.3 feet which provides an H_e/H_d ratio of 1.33 which is in accordance with EM 1110-2-1603. Exhibit Nos. 22 and 23, provide the output from programs H1107 and H1108, respectively. Exhibit No. 24 provides the discharge rating curve for the spillway.

e. Flip Bucket. Both the wet and dry dams will be provided with a flip bucket designed for a PMF event in accordance with EM 1110-2-1603. While the flip bucket is not an energy dissipator, it is an integral part of the energy dissipation system. The purpose of the flip bucket is to direct high-velocity flow (the jet) well away from the dam. The spillway throw distance was computed using equation 7-6 in EM 1110-2-1603. To provide additional scour protection, a concrete pad 100 feet in length will be provided downstream of the dam. Table No. 11 summarizes the features of the flip buckets for both the wet and dry dams. Exhibit Nos. 3A, 5A, and 7A of the main appendix provide details of the spillway and flip bucket for the 5.0-inch dry, 5.0-inch wet and 4.0-inch dry dams, respectively. Physical hydraulic model testing will be required to verify the design of the flip bucket.

TABLE No. 11

FLIP BUCKET FEATURES

Project	Invert Elev. (ft)	Bucket Rad (ft)	Lip Angle	Lip Elev.	Throw Distance (ft)
Wet	2273.0	40.0	30°	2279.0	210
Dry					
5.0-in.	2271.0	54.0	30°	2279.0	185
4.0-in.	2269.5	62.0	30°	2278.5	170

f. Spillway Routings. The adopted spillway design flood (PMF event - 'C' hydrograph) for Site 119 has a peak inflow into the reservoir of 480,000 cfs. Derivation of the spillway design flood is discussed in detail in Paragraph 8 of this addendum. For the wet, 5.0-inch dry and 4.0-inch dry dams, the initial pool elevation was assumed to be the maximum flood control pool elevations which are 2388.0 ft., 2368.0 ft. and 2358.0 ft., respectively. Starting the PMF routings at this elevation, the flood event was routed

through the project. The routing results are summarized in Table No. 12.

TABLE No. 12

PMF ROUTING RESULTS

Project	Peak Inflow (cfs)	Peak Outflow (cfs)	Maximum Pool Elev. (NGVD)
Wet	480,000	393,400	2424.0
Dry			
5.0-in.	480,000	392,000	2410.5
4.0-in.	480,000	391,900	2404.0

g. Maximum Pool Elevation and Top of Dam. The maximum reservoir level at the dam, obtained by routing the spillway design flood is elevation 2424.0 ft., 2410.5 ft., and 2404.0 for the wet, 5.0-inch dry and 4.0-inch dry dams, respectively. Top of the dam is placed at elevation 2427.0 ft., 2413.5 ft., and 2407.0 for the wet, 5.0-inch dry and 4.0-inch dry dams, respectively, which includes a minimum freeboard of 3 feet as required by ER 1110-8-2.

13. OUTLET WORKS

a. General. Considerations presented in paragraph 11-d-ii led to the adoption of gated outlets, of sufficient capacity to release water at channel capacity with the water level in the reservoir at the lower limit of the flood control storage zone. The outlet works will be slightly oversized, after completion of the project, due to diversion requirements. The outlet works will be located on the left bank and will consist of an upstream intake tower, sluices and standard hydraulic jump type stilling basin.

b. Intake Structure. The intake structure will house the inlet conduits, trash rack, service gates, emergency gates, wet wells and inlets for selective withdrawal, and the machinery for operating the gates. Three 8-ft x 15-ft gates will be provided for the main operation gates. Since no detailed layout of the intake structure or outlet works has been completed, the rating of the outlet works was based upon the orifice equation and designed to provide a minimum discharge of 10,000 cfs (channel capacity) at winter pool elevation for the wet dam. The same design was then used for the dry dam.

c. Selective Withdrawal. No hydraulic design computations were completed for the selective withdrawal system during this phase of study. To incorporate cost for selective withdrawal capabilities with a wet project, reviews were made of the Paintsville and Yatesville projects and similar features were incorporated into the Greenbrier Project. Two wet wells were used with ten 4-ft. x 4-ft. inlets. The two wells would discharge into two of the main sluices.

d. Stilling Basin. Energy of the water issuing from the three 8-ft. x 15-ft. sluices would be dissipated in the stilling basin by utilizing a hydraulic jump. The design of the basin was based upon guidance and criteria contained in Engineering Manual 1110-2-1602, "Hydraulic Design of Outlet Works". The design capacity of the stilling basin was selected as channel capacity (10,000 cfs). The basin is provided with an end sill and two rows of baffles. The floor of the basin and the tunnel portal are connected by a curved apron. The floor is set at elevation 2213.0 ft. to insure that when the design discharge is being passed, the theoretical jump will coincide with 85% of the tailwater elevation.

14. TAILWATER DATA

Water surface profile computations for the dam site were developed using the computer program HEC-2. The computations started approximately 3 miles downstream of the 119 damsite. Roughness coefficients used in the computations were 0.040 for the main channel and 0.050 to 0.080 for the overbank. Due to the lack of available high water data, sensitivity studies were completed on the water surface profiles by varying the roughness coefficients by +/- 10% and the starting water surface elevation by +/- 5 feet. Exhibit No. 25 provides the adopted tailwater rating curve and also provides curves reflecting the sensitivity studies.

15. DIVERSION

To capture the cost for diversion, a preliminary design for a diversion channel and dike was completed. The diversion channel would be a 75-ft wide trapezoidal channel located on the right descending abutment. The channel in conjunction with a dike (top elevation of 2245.0 ft.) would provide a 10-year level of protection.

16. RESERVOIR EMPTYING TIME

No reservoir emptying time computations were initiated for this phase of study.

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I. INTRODUCTION.

A. PURPOSE OF THE ENVIRONMENTAL APPENDIX. The purpose of the appendix is to present the results of a preliminary analysis of the potential environmental impacts of flood control dam alternatives on the Greenbrier River. This environmental study is only one of the reports generated to accomplish the stated purpose. The Huntington District has performed an evaluation study and developed appendices documenting Engineering, Economics, and Cultural Resources in support of the evaluation report.

This report addresses dam Site 119, two flood control (dry) dam alternatives and a multi-purpose (wet) dam alternative. Site 119 is located approximately 11 miles upstream of Marlinton, West Virginia, on the mainstem of the Greenbrier River. The riverbed is at elevation 2,223 feet. All dam alternatives will be arch-gravity and constructed with roller compacted concrete.

B. PHYSICAL GEOLOGY.

1. LOCATION. The Greenbrier River is one of the longest free-flowing major streams in the eastern United States. The rivers' main channel is formed by the East and West Forks and flows 153 miles through four West Virginia counties, Pocahontas, Greenbrier, Monroe, and Summers. The Greenbrier River has a drainage area of 1641 square miles. The potential dam sites are located upstream of the town of Marlinton in Pocahontas county.

2. <u>CLIMATE</u>. The Greenbrier River Basin lies in the temperate zone and experiences the usual seasonal variations in temperature. The Basin is affected by frontal air-mass activity. and is subjected to continental, polar, and maritime tropical air masses. Frequent and rapid changes in the weather occur due to the passage of fronts associated with general low pressure areas. The prevailing wind direction is from the southwest. Temperatures recorded at Marlinton have varied from -27 degrees Fahrenheit to a maximum of 100 degrees Fahrenheit. The normal annual rainfall is 44 inches.

3. <u>GEOLOGY</u>. Pocahontas County is entirely within the Allegheny Ridges and Allegheny Plateau, both subdivisions of the physiographic province of Appalachian. The Allegheny Ridges sub-province includes the sharp-ridged mountains southeast of the Greenbrier River, and the Allegheny Plateau sub-province includes the low-angle or nearby horizontal rocks northwest of the ridges.

II. BASE RESOURCES

A. TERRESTRIAL.

1. VEGETATION. Early forest vegetation prior to 1920 along the Greenbrier River included extensive hardwood stands of white oak and yellow poplar. Hemlock, a softwood, was an important source of tannin for the leather industry of the period. By 1920 the original forests were depleted of saw timber except for a few isolated areas of acreage. Farming (row crops, livestock) further reduced timber resources to narrow remnant stands of mixed hardwoods and softwoods along the floodplain and river banks. Small stands of white pine presently remain inside river bends where there is deep, well-drained, sandy substrate. The nine cover types designated by the USFWS, in an earlier study, are the Upland Forest, Bottomland Hardwood, Old Field, Palustrine Forest/Scrub Shrub, Unvegetated Shoreline, Palustrine Open Water/Palustrine Emergent, Urban, Cliff Face and Agricultural Land. The Upland Forest is the most extensive cover type in the basin. Agriculture land comprises the largest single cover type. The Bottomland Hardwood cover type is second in size. Palustrine Open Water / Palustrine Emergent, Palustrine Forest / Scrub-Shrub and the Unvegetated Shoreline are the wetland habitats in the floodplain.

Of the thirteen species of trees encountered in upper Greenbrier River, White Oak (<u>Quercus alba</u>) is the dominant tree.

Red Maple (Acer ovata) and White Pine (Pinus strobus) were found. White Oak communities are comprised of young, second-growth, healthy trees. Tree reproduction and survival is good with Red Maple, White Pine, Hemlock, White Ash, Black Gum. Green Ash and Cherry Birch the most frequent and largest canopy species.

The lower slopes having an east to northwest aspect include species of canopy trees consisting of Cherry Birch (Betula lenta), Basswood (Tilia americana), Sugar Maple (Acer saccharum) and Red Oak.

The bottomland forest along tributaries of the Greenbrier River are associated with Smooth Buckeye (Aesculus actandra) and Sugar Maple (Acer saccharum). The Buckeye-Sugar Maple Community is rich in groundcover species. In all, 94 species of herbs and woody seedlings are present in the study area community. Among the herbaceous flora, Hog peanut, Stonecrop and Blue Violet are important ground species. The overall vegetational composition in the project area is a excellent resource. Much of this resource is in the care of state and national forests.

2. ANIMAL. The project area contains a very diverse composition and community of animal life. Because of the diverse habitats in the study area a rich and complex animal ecosystem has evolved. Along the Greenbrier River, mink, muskrat, and beaver are in abundance. Many bird species are found in the area, both

residential and transient. Hunter use in the project area is forest game oriented. Deer, squirrel, raccoon, fox, ruffed grouse, and turkey are sought with excellent success. Cottontail rabbit and woodchuck are also found in abundance.

A herpetofauna (amphibians and reptiles) survey was conducted in the study area in 1987 by the USFWS Elkins office. Low-order streams and their adjacent riparian areas provide habitat for numerous species of herpetofauna, particularly salamanders. Many of these species are restricted to specific habitats, requiring a combination of shallow, swift flowing water, rocky boulder-stream bottoms, and shaded, cool, stream borders. Many tributaries of the Greenbrier River in the study area have these characteristics. Because these areas would be a part of the impoundment pool inundated as a result of the proposed project, this survey was important in determining losses. The survey shows a very diverse and rich herpetofauna in the project area.

B. AQUATIC.

1. FISHERY. The Greenbrier River contains ideal smallmouth bass habitat. The river provides excellent cover, a minimum of high muddy water during spawning and a gradient conducive to an excellent small mouth population. Walleye, although not regularly caught, are present in the deeper pools of the river south of Marlinton. Rock bass are the most abundant game

fish in the Greenbrier River and have been collected throughout the river. Flathead catfish are fairly abundant, while a few channel catfish are present in the deeper pools of the Greenbrier River. Carp, although not abundant, occur in some sections. Hogsuckers are the most abundant rough fish, and several forage species are present.

Many of tributaries of the Greenbrier River in the study area, particularly those located in Pocahontas County, support native brook trout populations. A number of tributaries are stocked with trout by the WVDNR on a put-and-take basis. The larger tributaries all contain good to excellent warm water fish populations, with small mouth bass and rock bass being the dominant game species.

A number of species found in the study area are of concern to the state. These include the tonguetied minnow (Exoglossum laurae), New River shiner (Notropis scabriceps), Kanawha minnow (Phenacobius teretulus), big mouth club (Nocomis platyrhynchus), and the fine scale saddled darter (Etheostoma osburni).

2. <u>BENTHIC</u>. Benthic macroinvertebrates are small bottom living invertebrates visible to the unaided eye. These organisms are relatively immobile and form an important part of the food chain of higher organisms and are directly affected by silt and changes in water quality. Life spans for most of these organisms

are more than one year. Critical change in water quality or habitat, even of short duration, can be detected through an evaluation of the presence or absence of these organisms. The Greenbrier River has a rich and diverse benthic population, indicating excellent water quality and substrate conditions.

At the request of the COE, the USFWS (Elkins Office) conducted a Greenbrier River native freshwater mussel fauna qualitative survey in 1986 and 1987. The survey was comprehensive and covered all of the Greenbrier River. This survey also included the river reach between Cass and Marlinton. Eight species of native freshwater mussels were collected during the survey. In the lower 29.5 mile survey reach, Actinonaias ligamentina carinata and Elliptio dilatata, were the most frequently encountered, 52.5 percent and 39.0 percent, respectively. Lampsilis fasciola Lampsilis ventricosa, Cyclonaias tuberculata, and Alasmondonta marginata, were also relatively common with 3.8 percent, 2.2 percent, 1.2 percent, and 1.0 percent. This study and a previous study of mussels in the Marlinton area clearly demonstrated the habitat preferences and headwater species composition. This is most evident of the dominance of Lasmigona subviridis in the headwaters and the absence of A. l. carinata and the complete reversal of this situation in the lower reach. In relative terms, the upper Greenbrier River provides little suitable habitat for freshwater mussels because its substrate consists predominately of packed coarse gravel, cobble, boulders, and bedrock. Only three

species are known from this upper section; A. marginata, L. subviridis, and E. dilatata. Descending the river, better mixture of clean-swept silt, sand, and gravel habitats preferred by mussels fill the more frequently encountered interstitial spaces between the cobbles and boulders. E. dilatata and A. marginata appear to have a wider range of habitat preference while Tritogonia verrucosa and L. subviridis have very narrow habitat preferences, silt and sand, respectively. Species diversity and abundance increased, descending the river.

3. WATER QUALITY. Water quality in the Greenbrier River within the study area is excellent. The data show adequate dissolved oxygen, water temperatures, pH and dissolved nutrients necessary to support a good warm water fishery. Pollution influencing water quality within the study area is primarily from a tannery located upstream of the dam sites and from domestic sewage. Other sources of pollution influencing the Greenbrier River are mainly in the form of increasing turbidity levels and suspended sediments as a result of limited agricultural grazing, and logging practices.

C. ENDANGERED SPECIES. The only endangered species listed by the Department of the Interior which could potentially be affected by the project is the Indiana bat, Myotis sodalis. Riparian habitat of potential value to this species near cave regions could be altered by the project. A small hibernating

population of Indiana bats is known from Cass Cave, located near Cass, West Virginia at the Greenbrier River, approximately 16 air miles upstream of the project site.

A number of animal and plant species found in the vicinity of the study area are of concern to the State, however, their actual status is unknown. These data were compiled by the WVDNR, Heritage Trust Program. and WVDNR, Division of Wildlife Resources. These include the New River Shiner, Notropis scapbiceps, big mouth chub, Nocomie platyrhynchus, tonguetied minnow, Exoglossum laurae, Kanawha minnow, Phenacobius teretulus, five scaled saddle darter, Etheostoma osbuani, Appalachian darter, Percina gymnocephala, cave salamander, Curycea lucifuga, false melic, Schizachne purpurescens, and swamp lousewort, Pedicularis lanceolata.

The Corps, WVDNR and USFWS jointly conducted a bat survey to determine the use of riparian habitat by Indiana bats in the project area. The survey was inconclusive in its objective. Many bats were mist netted but the Indiana bat was not found.

III. IMPACTED RESOURCES.

A. WET DAM.

1. TERRESTRIAL.

a. VEGETATION. The wet dam concept will require acquisition of approximately 3,446 acres of land. Approximately 1,520 acres of land will be inundated by the summer pool elevation. This represents all habitat types in the project area. A 1976 edition of Habitat Evaluation Procedure (HEP) was performed on the same type lands and habitats that exists in the study area in 1989. This HEP gave an overall value to all lands at .75 or one and a half times the average. Average in the HEP is .5 out of a possible 1.0. In addition to the acreage in the summer pool, land above will be impacted to a lesser degree because of storage of flood flows. To account for these losses 300 additional acres was used. If we assume a total loss of 1,820 acres of habitat at 1.5 times value, this would equal 2,730 acres. Since any replacement land is existing then a doubling requirement would be 5,460 acres to equal the vegetation losses. Tail water releases, despite erosion control efforts, could have some adverse impacts downstream of the dam.

b. ANIMAL. The animal losses associated with the wet dam would and will be on the same loss base as the vegetation.

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It will become a matter of habitat loss in acres and value. The animal losses and the methodology of replacing loss populations will be an addition effort, to the vegetation loss replacement.

The project tail water would be changed significantly by the project. The flow release regime would be changed to accommodate recreational use and to provide flow augmentation during low flow periods as mitigation for stream losses due to reservoir development. The Greenbrier River has developed its great diversity and richness of habitat by being exposed to great flow changes on an annual and geological time scale. Changes in this regime could cause effects on the river many miles downstream. These impacts from changed tail water releases will change not only the fishery but all aquatic systems. Some of these impacts will be positive and some will be negative. More water during the ordinary dry periods will enhance some species, such as fish, but could be negative in the life cycles of some benthic species that depend on the dry periods.

b. <u>BENTHIC</u>. The wet dam concept will completely eliminate the diverse benthic community of the Greenbrier River in 13.3 miles of the river. In addition the areas above summer pool in the upper reaches will be more frequently inundated and will suffer from silt and sediment deposition.

Tail water benthic communities will also be impacted by changing the flow regime. Changes in flow regime will change species composition and could eliminate many species that have evolved under the present regime while enhances others.

The mussel populations are very low in the project area and will disappear entirely in the project pool impact areas. Deep water, temperature and head water silt and sediment will act to eliminate the species now there.

c. WATER QUALITY. The wet dam, if implemented, would completely change the water quality of the 13.3 miles of the project pool. The water would be pooled and develop into a stratified lake during summer months. The river as it now exists is one which supports a diverse fishery and benthic. The created lake will have a less diverse fishery and benthic. The lake will change the water quality significantly in many ways. For instance, the steep sided lake could have warm water at the surface and a very cold and sometimes oxygen depleted, hypolimnion. This situation will cause diversity to lessen and an artificial fishery will need to be implemented and sustained by management.

3. ENDANGERED SPECIES. The wet dam, by eliminating 13.3 miles of riparian and floodplain habitat, could have adverse effects on the endangered Indiana bat. At this time effects on the state list of concerned species is unknown.

B. DRY DAM.

1. TERRESTRIAL.

a. VEGETATION. The dry dam concept will have some adverse impacts on the project area, however, these adverse impacts will be relatively less than the wet dam concept. The dry dam will have an outlet works that will pass normal and bank-full release flows. Flood flows will be held to prevent damage downstream. These flood level impoundments will vary according to rain fall in the upper basin. Most flood flows held back by the dry dam will be released in a 3 day maximum period. These impounded waters will effect the vegetation according to the tree and scrub/herbaceous water tolerance characteristics. The quick release character of the dry dam will probably have the following adverse impacts. First, the water intolerant species will die from inundation. Second, in many cases the mature tree will survive but be unable to reproduce and the result will be no species recruitment in the impacted area. In most dry dam areas the older species survive in an isolated situation with open grass areas between. The steepness of the hills in the project pool could cause a temporary erosion problem from increased inundation frequency. The amount of affected acreage is not available in sufficient detail to analyze actual quantitative losses.

b. ANIMAL. The dry dam effect on animal life in the

project area will be adversely impacted according to the gradient of the stream and the duration of flood pools. Most animal life addressed in this section are not entirely water dependent and can move as flow impoundment necessitates. Because of the relatively short duration of held flood flows most species will move upstream or uphill to avoid impact.

2. <u>AQUATIC</u>.

a. <u>FISHERY</u>. The dry dam concept will have adverse impacts to the fishery by more frequently inundating the river behind the dry dam. This action will cause increased silt and sediment to be deposited on the river bed. Also the temporary lake will eliminate species such as darters and riffle and run species by making the water and habitat deep. Most of the impacts will be close to the dam. The quick rise and fall of the Greenbrier flood events in the project area will lessen most long term impacts on the fishery.

In the tail water area, adverse impacts will occur. These impacts will be caused by temperature changes caused by the impounded water even if of short duration. Flow releases will be held to bank-full condition when possible and less impact will occur.

b. <u>BENTHIC</u>. The dry dam concept will have

significant adverse impacts from the dam upstream. These adverse impacts will lessen upstream because the inundation frequency will be diminishing. The diversity of the benthic will be adversely impacted by the dry dam.

Mussel populations will be impacted adversely from the impounded waters. These impacts will lessen going upstream from the dry dam because of the reduced inundation frequency. Sediment deposition will be the most adverse impact on the mussel populations in the dry dam concept.

c. WATER QUALITY. Water quality under the dry dam concept will have limited adverse effects. The water quality of the river could change in temperature, oxygen, nutrients, and other physical parameters such as excessive silt and sediment load. The cause of this change would be the impounding of water behind a dry dam. The release of these held flood flows could be adverse to the tail water areas for the same reasons. However, these impacts will be very limited compared to the wet dam.

3. ENDANGERED SPECIES. The only DOI recognized endangered species in the dry dam project area is the Indiana bat. This bat uses the riparian areas of rivers like the Greenbrier during the summer. The impacts will be directly related to loss of riparian habitat in the dry dam impacted area. These impacts should not be significant.

IV. MITIGATION MEASURES AND COSTS.

A. WET DAM.

1. TERRESTRIAL.

a. VEGETATION. Approximately 3,446 acres of land is required to be purchased for the wet dam concept. These lands consist of all terrestrial habitat types recognized in the USFWS reports on the Greenbrier River terrestrial resources. A partial HEP was conducted on the project area by the WVDNR, USFWS and the Corps in 1989. This study produced a overall terrestrial habitat value of 0.75 out of a possible 1.00. The average forest of this type would be ranked at 0.50. Using this assumption, the comparative value of the mitigated lands would be approximately one and a half times. Therefore 1.5 X 1820 acres equals 2730 acres of mitigation lands needed. To equal the original lands, however, the forest to replace the loss of lands is impossible to purchase, physically and financially. The only realistic mitigation solution is to enhance the local and adjacent state and federal forests. However, when you wish to replace forest land with forest land you have to consider that the new or mitigated forest land is already there and has equal value. Therefore, you have to double the mitigated land size requirements form 2,730 acres to 5,460 acres of enhancement land. Value of an enhanced mitigation effort per acres ranges a very wide monetary spectrum. For instance, some enhanced

lands cost more than $1,600 per acre. These lands required intensive input and management efforts that were a major factor in the high cost per acre. The costs included in stream structure and other high cost items. Because the National and State Forest in the project vicinity are intensely managed at this time a much lower cost per acre can and should be used. Using the realistic cost of $100.00 per acre at 10,338 acres equals a total terrestrial mitigation cost of $546,000.

This mitigation plan is based on a realistic and implementable approach. The state and federal lands have management plans in place and these plans can be used to guide mitigation efforts. The mitigation monies and efforts could be a joint effort by the local forest management and the Greenbrier River mitigation team. This mitigation approach would be useful to the local forest ecosystem and affordable for the project costs.

Other environmental disturbances on project lands during project construction will be undertaken in a sound environmental engineering procedure.

b. <u>ANIMAL</u>. The animal mitigation is included in the above mitigation concept.

2. <u>AQUATIC</u>.

a. <u>FISHERY</u>. The following mitigation concept includes the

benthic and water quality impacts on the project. The loss of 13.3 miles of the Greenbrier River, as a result of the Wet Dam, cannot reasonably be replaced. With the loss of this section of lotic water, it is necessary to attempt to reduce the harshness of the loss through mitigation. Mitigation for adverse impacts is defined as measures to avoid or limit actions which impact upon fish and wildlife resources, to restore impacted habitats, or preserve those habitats which can be expected to be otherwise lost without preservation, or to compensate for losses through the substitution or more intensive management of similar resources.

The loss of 13.3 miles of the Greenbrier River can be quantified in the following way. The river has an average width of 275 feet, therefore 275 feet X 13.3 miles equals surface acres of 443.3. Assuming the average value of a stream to lake system is ten times on the side of the stream, then, the lake value of the river is 10 X 443.3 which equals 4,433 surface acres. The created lake will have a surface acreage of 1,520 (summer minimum). Therefore, 4,433-1520 equals 2913 surface acres that the lake will have in losses compared to river value. This loss can be partially offset by an increased flow regime from the lake downriver during the dry periods of the year. Although the argument can be made that river water does not equal enhanced habitat, for this exercise we will assume it serves as a reasonable proxy. Therefore the increased flows can be considered offsetting the losses of surface acres. The increased flows will have a partial enhancement value

on the downstream river that can be considered equal to losses of surface acres.

The lake will have a two story fishery potential. To further offset and mitigate the loss of river habitat compared to lake habitat, the following measures are proposed;

* Nearby the project site the State of West Virginia has a cold water trout hatchery (EDRAY). This hatchery can be used to develop a deep water fishery in the lake by supplying trout to the lake. In order to make the hatchery able to meet this increased capacity of trout needed, two additional ponds can be built on the present hatchery. Using the costs of Bowden State Hatchery recent expansions, an average size additional trout hatchery pond costs approximately one million dollars. Therefore, the costs of adding two ponds to Edray hatchery would be approximately two million dollars.

* The tailwater area can also become an excellent trout fishery with great recreational potential. Trout fishing would attract many people and have a positive financial impact on the Marlinton area. Bottom releases from the dam would assure the water temperature needed for trout habitat. Nutrient levels might be questionable for a trout fishery, but could be enhanced artificially. Because of the steepness of the valley downstream of the dam (cool temperatures), the trout fishery

could be maintained ten or more miles. This would extend the trout fishing area to the vicinity of Marlinton. The present hiking trail can be used for fisherman and stocking access. The cost of this measure would be relatively low because the stream structure is already suitable for trout fishing. A good estimate for the costs of this tailwater trout endeavor would be about $200,000 maximum to implement a stocking program as well as nutrient enhancement if needed.

b. <u>BENTHIC</u>. Same as above.

c. <u>WATER QUALITY</u>. Same as above.

B. <u>DRY DAM</u>.

1. <u>TERRESTRIAL</u>.

a. <u>VEGETATION</u>. The dry dam will release river flows up to bank full conditions downstream of the dam.

The dam will hold back flows in excess of bank full. These ponding flood flows will have impacts based upon seasonal (most high water will be in the winter-spring) flows and flood flow retention duration. The retention times are relatively small because of the rivers steep gradient in this section. Therefore it is estimated that the first five miles above the dam can be considered adversely

impacted by the dry dam. Based upon the wet dam impacts, a conservative number of adversely impacted areas would be; 800 acres of land with negative impacts. Value of the land, according to partial HEP numbers is 1.5 X 800 equals 1200 acres. The 1200 acres would double on new forest lands, therefore 2,400 acres would be needed for mitigation enhancement. These mitigation areas will be confined to enhancing project lands only. Using the same estimated assumptive $100 per acre forest enhancement numbers used in the wet dam mitigation, then $100 X 2,400 acres equals a mitigation cost of $240,000. As in the wet dam concept, other disturbed vegetational areas of the project will be offset by good environmental engineering practices.

b. ANIMAL. Mitigation of the negative vegetation impacts will also mitigate impacts to animal life.

2. AQUATIC.

a. FISHERY. The dry dam adverse impacts to the Greenbrier River fishery, benthic, and water quality are as follows; the dry dam ponding regime will determine the impacts to the aquatic ecosystem. Using the same impact ponding as the above wet dam, five miles of negative impact seems reasonable. Again the value of the five miles will be 1.5 X five miles equals 7.5 miles. So, if 7.5 miles of stream are improved, then 15 miles of river enhancement is needed. The 15 miles of river enhancement can be

accomplished on the immediate Greenbrier River and its tributaries. Further investigations will be needed to determine where and what kind of river enhancement measures can be implemented. The cost of river enhancement measures using detailed investigations for other District studies is approximately $200,000 per mile. Because of a very much reduced intensity level of the Greenbrier enhancement measures, the realistic costs per mile would be in the order of $50,000 per mile of mitigated stream. Therefore, $50,000 X 15 equals $750,000.

b. <u>BENTHIC</u>. Included above.

c. <u>WATER QUALITY</u>. Included in fishery mitigation.

V. CONCLUSIONS. The cost and losses determined in this study are based upon assumptive data and any further study of the Greenbrier River mitigation costs will require further studies.

The table which follows summarizes the mitigation costs which have been developed for this study. Mitigation costs shown for the dry dam are applicable for alternative dry dam projects having flood storage capacities equivalent to 2", 4", and 5" of run-off.

EXECUTIVE SUMMARY

A Cultural Resources Reconnaissance consisting of a literature and records search was completed for the Greenbrier River Evaluation Study. The literature and records search concentrated on the Greenbrier River Basin in Pocahontas County with special emphasis on the area above River Mile 119.

The two Dry Dam alternatives (designed to accommodate 4" and 5" of runoff) at River Mile 119 may adversely impact eight potential archeological sites recorded in the project area by the U.S. Forest Service. These sites appear to be in areas that may be periodically inundated. The extent of these impacts cannot be evaluated until the cultural resources survey is completed and the significance of all sites is determined.

The multi-purpose reservoir will adversely impact the same eight sites by permanently inundating the sites and making them inaccessible for future archeological excavation. This project will also adversely impact unrecorded sites in areas that will be developed for recreation and management. The extent of these impacts cannot be fully evaluated until a comprehensive cultural resources survey is completed and the significance of all sites is determined.

PROJECT DESCRIPTION AND HISTORY

The purpose of this Greenbrier River Evaluation Study is to evaluate several alternatives that would reduce or eliminate flooding within the Greenbrier River Basin for potential economic feasibility and to determine if a Federal interest in continuation of the feasibility study still exists.

The preliminary study completed in 1989 indicated that a mainstem dam on the Greenbrier River located between Marlinton and Cass, West Virginia, had the greatest potential for economic feasibility.

All available information was reviewed and those alternatives chosen for this Evaluation Study appear to have the greatest potential for economic feasibility. Dry Dams with no permanent pool, operated only for flood control, were evaluated at both Site 110 and 119 because these sites have different advantages and disadvantages with respect to this type of structure.

The other dam considered as part of this study was a multi-purpose dam at Site 119 having a seasonal pool with 1250 to 1500 surface acres at an elevation between 2336 and 2349. This dam appears to provide excellent land use potential along the lake with a large number of access possibilities.

The three projects presently being considered for mainstem dams are located on the Greenbrier River at River Mile 119, about eleven miles upstream of Marlinton, West Virginia. These projects which include two dry dams designed to handle 4" and 5" of runoff and a multi-purpose reservoir are the subject of this report.

Authority for the Greenbrier River Evaluation Study was granted by Resolution of the Public Works Committee of the U.S. House of Representatives on 10 May 1962. Following the disastrous flood of November 1985, studies underway at Marlinton, West Virginia, were re-directed toward assessing measures for reducing flood damages throughout the Greenbrier River Basin.

ENVIRONMENT

The Greenbrier River is one of the longest free-flowing major streams in the eastern United States. The river's main channel is formed by the East and West Forks and flows south 167 miles from Durbin in Pocahontas County, West Virginia, to the New River at Hinton, Summers County, West Virginia. The entire river is located in the Allegheny Mountain Section of the Mixed Mesophytic Forest Region of North America. Mountain ridges and valleys are oriented north to south and are connected by narrow

streams. Elevation in the area varies from 4840 feet near Bald Knob to 2130 feet along the banks of the Greenbrier River at Marlinton, West Virginia (Evans 1988).

Climate of the area has a north-temperate affinity with a total mean annual rainfall of 48 inches and a mean snowfall of 50 inches per year. The mean maximum and minimum temperature for January is 44 and 22 degrees. For July the mean maximum and minimum temperatures are 80 and 56 degrees (West Virginia Department of Natural Resources 1968).

Factors of temperature and precipitation, along with characteristics of topography and soil, have resulted in a northern hardwood vegetation type characterized by a mosaic of deciduous, coniferous and mixed forest communities. Braun (1950) classifies this vegetation as a mixed mesophytic forest type.

Soils of the upper Greenbrier River include bottomland soils with 0-3% slopes and upland soils with 3-80% slopes. Bottomland soils include Tioga Loam, Chavies Loam, Lebdell Loam, Chargrin Silt Loam, Potomac Cobbly Loam, Allegheny Loam, Holly Silt Loam and Orrville Silt Loam. Upland soils include Berks-Dekalb complex, Shouns Silt Loam and Laidig Channery Loam (Fiegal 1988).

The geology of the upper Greenbrier River is characterized by interbedded shales, sandstone and limestone. To the west, the Devonian formations are overlain by Mississippian shale and sandstone. Overlying the sandstone is Greenbrier limestone which outcrops throughout most of the upper Greenbrier River.

The basal (Hillsdale) member of the Greenbrier limestone contains nodular chert (Hillsdale chert) which was used by prehistoric Indians for stone tool manufacture (Lesser 1990).

CULTURE HISTORY

The Paleo-Indian period has been consistently radiocarbon dated in the western United States to 10,500 BC. Traditional views hold that Paleo-Indians were highly mobile big game hunters who followed herds of mastodon and caribou. Current information from the Shawnee Minisink Site in Monroe County, Pennsylvania, reflected a much different picture. Dent (1981:79) reported that the Paleo-Indian levels at this site included carbonized seeds such as acalypha, blackberry, chenopod, hawthorn plum, hackberry and grape. The faunal assemblage suggested that these people were heavily dependent on fish (U.S. Army Corps of Engineers 1990).

The Early Archaic Period dates from 8000 to 6000 B.C. and is characterized by broad spectrum hunting and gathering. Indians hunted primarily deer and gathered a variety of nuts, berries and

other plants. Projectile points become smaller and have serrated edges (U.S. Army Corps of Engineers 1990).

The Middle Archaic Period dates from 6000 B.C. to 4000 B.C. It is characterized by the addition of ground stone tools to the artifact inventory. Ground stone artifacts made by pecking, grinding and polishing include adzes, axes, bannerstones, and pendants. Ground stone tools such as manos, mortars and pestles, and nutting stones are interpreted as plant food processing artifacts and indicate increased use of plant foods (U.S. Army Corps of Engineers 1990).

The Late Archaic Period dates from 4000 B.C. to 1000 B.C. It was a time of population increase with more complex social organization. Several wild plants are domesticated during the Late Archaic. These include East Mexican Agricultural Complex plants such as gourd and squash and Eastern United States Agricultural Complex plants such as lambsquarter, marsh elder and sunflower (U.S. Army Corps of Engineers 1990).

The Early Woodland Period dates from 1000 B.C. to 200 B.C. Two major developments include the manufacture of pottery and the construction of burial mounds (U.S. Army Corps of Engineers 1990).

The Middle Woodland Period dates from 200 B.C. to A.D. 400. Classic Middle Woodland occupations are best known in Central Ohio where the Hopewell flourished and built numerous large earthworks. In West Virginia the Armstrong culture is most representative of Middle Woodland. Indians continued living in scattered hamlets and left no traces of earthworks. Occasionally mica or prismatic bladelets made of Ohio Flint Ridge flint are found on these Middle Woodland hamlets (U.S. Army Corps of Engineers 1990).

The Late Woodland (A.D. 400 - 1200) was a period of transition characterized by population migrations and diffusion of major technological and social innovations. About A.D. 700, the bow and arrow was introduced. Shortly thereafter corn was introduced. During most of this period, local populations continued to live on farmsteads and in small hamlets (U.S. Army Corps of Engineers 1990). The type site for the Late Woodland Buck Garden Complex (46NI49) is located in Nicholas County. Nearly all rockshelters in central West Virginia contain Buck Garden pottery, along with triangular projectile points and extensive faunal remains, which indicates these sites were extensively used as hunting and gathering stations from A.D. 700 to 1,200.

The Late Prehistoric period dates from A.D. 1200 to 1700. By A.D. 1200 Woodland horticulture was replaced by intensive corn agriculture and Woodland hamlets along major rivers were replaced by large Fort Ancient villages. Principal crops were corn, beans

and squash. Diagnostic artifacts include triangular arrow points and shell tempered pottery (U.S. Army Corps of Engineers 1990). Although numerous Late Prehistoric villages have been recorded on the New River none have been recorded on the Greenbrier.

Davis (1978) has divided the Historic Period in the Monongahela National Forest into five sub-divisions. These periods with some modifications will be used in this report.

The Early Exploration and Settlement Period (A.D. 1700-1800) began in the Greenbrier Valley began with Jacob Marlin and Stephen Sewell. The two spent the winter of 1750-1751 together at their camp in the delta formed by Marlin Run and a slough or drain near the east bank of Knapp's Creek (Price 1901:105; Clarkson 1990:5). The two separated over an argument regarding religion and Sewell (the Protestant) moved to a hollow sycamore tree, within speaking distance of Marlin (the Catholic) who remained in the cabin they had built (Price 1901:105). Sewell later moved alone to the New River where he was found slain by Indians. Marlin returned to Virginia (Price 1901:105; Clarkson 1990:5, Davis 1978:59).

The next white settlers along the Greenbrier River were John Lewis and his son Andrew, who came to the area in 1751 as agents and surveyors for the Greenbrier Land Company. John Lewis became entangled in dense growth of greenbriers growing in the valley, and hence named the Greenbrier River (Comstock 1974).

By 1770, many settlers, mostly of Scotch-Irish descent, had settled in the area (Clarkson 1990:5). Several forts were established in the upper Greenbrier valley in response to Indian attacks during the Revolutionary War (Davis 1978:60).

The Internal Development and Improvement Period (A.D. 1800-1860) was characterized by community growth which was largely dependent on the development of roads. This community growth led to the development of present day Pocahontas County which was formed in March 1821 from parts of Bath, Pendleton and Randolph Counties, Virginia. The southern boundary was changed in 1824, adding 60 square miles from Greenbrier County. The county was named for Pocahontas, the daughter of Indian Chief Powhatan (Comstock 1974:37-39).

A number of roads constructed in the area prior to the Civil War served to open communication between the major valleys. The early major transportation routes were the trails made by the buffaloes and the Indians. Around 1836, better roads to and from the county were begun. The Warm Springs & Huntersville Turnpike was completed in 1838, bridging every stream from Huntersville to Warm Springs (Price 1907:73). This was the first public road in present day Pocahontas County. A peddler set up for trade at the home of John Bradshaw in present day Huntersville where hunters

brought in their pelts, venison, ginseng, etc., hence the name Huntersville (Comstock 1974:42). The Staunton & Parkersburg Pike was under construction 2-3 years later. About 1854, the Huntersville & Marlinton Turnpike was begun--the same year the Lewisburg & Marlinton Turnpike and the Greenbrier Bridge at Marlinton were planned. All were completed by 1856 (Price 1907:73).

During the Civil War Period (A.D. 1860-1865) military activities in the area consisted primarily of efforts to secure the Staunton and Parkersburg Turnpike and the Huntersville and Warm Springs Turnpike. By early 1862, Federal troops had gained control of these roads and, after that time, activities were restricted to local skirmishes. Local residents mostly sided with the South and contributed both manpower and supplies to the Confederate forces stationed in the area (Davis 1978:70).

The Lumbering Period (A.D. 1865-1920) actually had its beginnings prior to the Civil War. During and after the Civil War, as the immense timber stands became known, speculators and financiers became interested in the area, but the general north-south orientation of the Alleghenies and the ruggedness of the topography slowed the development of the timber industry in the area (Clarkson 1990:7).

The Greenbrier River was used to transport logs in the spring when it became swollen. The use of the river for this purpose dates to at least 1825. From 1849 until the Civil War, logs were floated on the Greenbrier to small mills at Riverside near Marlinton (Clarkson 1990:7).

Present day Marlinton was known as Marlin's Bottom (named after the first settler Jacob Marlin) until 1887. The farms known as Marlin's Bottom were purchased in December 1880 by Colonel John T. McGraw. At that time the town was laid off in lots and was later renamed Marlinton (WVGS 1929:15; Clarkson 1990:19). In 1891 the county seat changed from Huntersville to Marlinton.

Logging as a major industry began with the formation of the Greenbrier Lumber Company in 1871. The company constructed two sawmills near Ronceverte. The "Big Mill" had six boilers, one 1250 hp engine, 1 muley saw, 1 circular saw, 1 gang saw of 36 blades, 1" apart, and had a sawing capacity of 120,000 feet per day (Clarkson 1990:9).

Prior to the construction of the railroad during the late 1800s, lumbering was a local industry. Timber exported from the area came primarily from the middle course of the Greenbrier River and had to be rafted to downstream mills. The upper reaches of the Greenbrier and its tributaries were largely inaccessible. With the development of the railroad, the lumbering industry operated with high intensity for a period of

30 years, at which time most of the area's marketable timber had been cut. With this the region returned to agricultural pursuits dominant during the mid-nineteenth century and those industries supported by peak lumber production began to disappear. Many towns and commercial enterprises were abandoned as were all but the main railroad lines (Davis 1978:87).

The Post-Lumbering Period Decline (A.D. 1920-Present) coincides with the development of the National Forest. Logging companies operating within the area during the early 1900s employed widespread clearcutting as a means of harvesting timber. The practice resulted in the accumulation of heavy slash and often resulted in forest fires that destroyed the humic topsoils. As a result, flooding became more frequent. In March 1907, disastrous flooding occurred within the Monongahela River basin resulting in approximately $100 million in damages to agricultural land along the river and another $8 million in damages to the city of Pittsburgh. This catastrophe led to Congressional hearings in January 1908, and culminated in the Weeks Law of 1911, enabling the creation of national forests in the eastern United States in order to protect the watersheds of navigable streams (Davis 1978:88).

On April 28, 1920, a presidential proclamation was signed by President Woodrow Wilson creating the Monongahela National Forest on the headwaters of the Cheat and Greenbrier Rivers. Much progress was made during the 1930s in land acquisition and forest improvement. The Civilian Conservation Corps (CCC), active in the National Forest between 1933 and 1942, was responsible for building roads, trails, telephone lines and reforestation of the many denuded slopes. CCC workers were supervised by Forest Service and Park Service personnel and were housed in camps built and operated by the Army. Each camp housed approximately 220 men and normal facilities included five barracks, a kitchen, mess hall and offices (Davis 1978:89).

In the past two decades tourism and historic preservation have become important in the revitalization of the local economy. Besides the modern Snowshoe Ski Resort, Pocahontas County has several historic tourist attractions among its 12 National Register Sites. These include the Droop Mountain Battlefield, the Pearl Buck House, the National Radio Astronomy Observatory, the Cass Scenic Railroad and the Cass Historic District.

Cultural Resources

The National Register of Historic Places was checked and none of the 12 sites listed for Pocahontas County are located in the project area.

No archeological sites were recorded in the West Virginia State Historic Preservation Files in the project alternatives, however, no archeological surveys were undertaken in the area.

The United States Forest Service recorded the following eight sites in or near the project area in its 1978 Cultural Resources Overview of the Monongahela National Forest. None of the sites were field checked and none were evaluated for the National Register of Historic Places.

Site 03-025

This is an historic band saw mill site in the Raywood vicinity. It is unknown if there are any archeological remains at the site. The site is owned by a non-Federal entity, and has not been evaluated for National Register of Historic Places significance.

Site 04-001

This is an historic band saw mill site in the vicinity of Clover Lick. It is unknown if there are any archeological remains at the site. The site is owned by a non-Federal entity, and has not been evaluated for National Register of Historic Places significance.

Site 04-003

This is a prehistoric mound site located in the vicinity of Clover Lick. The site has not been evaluated for National Register of Historic Places significance and is owned by a non-Federal entity.

Site 04-006

This site is an historic archeological sites listed as unidentified structures and is located about one mile downstream from Clover Lick. The site has not been evaluated for National Register of Historic Places significance and is owned by the U. S. Forest Service.

Site 04-094

This site is listed as an historic salt spring located in the Clover Lick vicinity. The site has not been evaluated for National Register of Historic Places significance and is owned by a non-federal entity.

Site 04-098

This is an historic saw/grist mill site located in the Clover Lick vicinity. The site has archeological remains. The site has not been evaluated for National Register of Historic Places significance, and is owned by a non-Federal entity.

Site 04-105

This historic circular saw mill site is located in the Clover Lick vicinity. The site has archeological remains. The site has not been evaluated for its National Register of Historic Places significance and is owned by a non-Federal entity.

Site 04-112

This historic circular saw mill site is located in the vicinity of Stony Bottom. The site has archeological remains. The site has not been evaluated for its National Register of Historic Places significance and is owned by a non-Federal entity.

The most potentially significant resources in the project area are in the vicinity of Clover Lick. The U.S. Forest Service lists a salt spring, Indian Mound, band saw mill, saw/grist mill, circular saw mill and a historic archeological site in this vicinity.

The history of Clover Lick begins in the late 1700s with Jacob Warwick who rented what is currently Clover Lick from the Lewis family to herd his cattle for the winter. Warwick later traded his Kentucky possessions for a portion of the Clover Lick lands to a man named Alexander Dunlap (Price 1901:237).

Warwick originally lived in a cabin in Clover Lick, and eventually moved to Bath to raise his children. The last fort to be built along the upper Greenbrier was Fort Clover Lick, the fortified home of Jacob Warwick, which was built before 1784 and destroyed by Indians in 1786 (Davis 1978:61, McBride and McBride 1991:48). When he returned to Clover Lick, the log cabins were deemed unfit for occupancy. He eventually built a large mansion for himself and his family. The mansion was used extensively for preaching services. The mansion was removed to make way for a Dr. Ligon to build his residence, and was burned in 1884 (Price 1901:237-238).

The main route for emigration from Maryland, Pennsylvania and other points north and northeast passed by Clover Lick to Kentucky and Ohio. This made Clover Lick one of the most public and widely known places in the whole country (Price 1901:237).

Frank Wise incorporated the F.S. Wise & Sons lumber company in February 1912 at Clover Lick. The land for the company bordered the Greenbrier River and was situated along Sitlington Creek and Laurel Run. In 1917, A.D. Neill and Company purchased the F.S. Wise & Sons company in its entirety ((Kline n.d.:9). Some of the saw mills listed as potential archeological sites may be attributed to these companies.

Impacts of Proposed Plans

The two Dry Dam alternatives at River Mile 119 may adversely impact the eight potential archeological sites recorded in the project area by the U.S. Forest Service. These sites appear to be in areas that will be periodically inundated. The extent of these impacts cannot be evaluated until the cultural resources survey is completed and the significance of all sites is determined.

The multi-purpose reservoir will adversely impact the same eight sites by permanently inundating the sites and making them inaccessible for future archeological excavation. This project will also adversely impact unrecorded sites in areas that will be developed for recreation and management. The extent of these impacts cannot be fully evaluated until a comprehensive cultural resources survey is completed and the significance of all sites is determined.

Recommendations

If the Greenbrier Project proceeds to the next planning stage the following cultural resources studies will be necessary:

-- An updated Cultural Resources Reconnaissance Report will be completed which will include an archeological and historic survey of the maximum pool area for the wet and dry dam projects. This Cultural Resources Reconnaissance Report will be coordinated with the West Virginia State Historic Preservation Office.

-- Upon completion of the Cultural Resources Reconnaissance Report and coordination with the State Historic Preservation Office, a Cultural Resources Survey should be implemented. The Survey will include a detailed on the ground inspection of the entire project area, identification of all archeological sites and structures over 50 years old, evaluation for the National Register of Historic Places of all archeological sites and structures. The survey and evaluation may include archeological testing of potentially significant sites and deep testing in floodplain areas.

-- Upon completion of the Cultural Resources Survey and coordination with the State Historic Preservation Office a Memorandum of Agreement will be negotiated with the National Advisory Council on Historic Preservation to cover the mitigati of National Register eligible sites in the project area.

-- Upon initiation of project construction the cultural resources mitigation will be implemented under the terms of the Memorandum of Agreement negotiated with the National Advisory Council and SHPO. Mitigation will include excavation of significant impacted archeological sites and the moving or documentation of significant historic buildings.

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I. OVERVIEW OF STUDY AREA

A. Location and General Overview. The Greenbrier River is located in southeastern West Virginia and flows 167 miles from its headwaters in northeastern Pocahontas County to its confluence with the New River at Hinton. The Greenbrier River Basin lies mainly within Greenbrier and Pocahontas Counties, although a small portion near the mouth extends into Summers and Monroe Counties.

In general, the Greenbrier River Basin is sparsely developed. All along the river are scattered clusters of permanent homes, seasonal cabins, and campers. Nonresidential development is very sparse except in the few urban reaches of the basin. Large reaches of the river are inaccessible by primary or secondary roads.

The four most important urban centers that have developed along the Greenbrier River are the towns of Marlinton, Ronceverte, Alderson, and Hinton. However, these towns are not of great size. Most of the flood-prone structures in the basin are located in nonurban areas.

Economic development in the Greenbrier River Basin has been very slow since the 1970s. From 1979 to 1988, the basin experienced a loss of population, a very slight increase in the number of jobs accompanied by substantially declining total earnings. Personal income increased during this period, presumably the result of increased transfer payments. In 1988, the ratio of total earnings to total personal income was 53 percent for the Greenbrier River Basin-- much lower than that of the state and the nation, at 66 percent and 73 percent, respectively.

B. Population. The Primary Study Area (PSA) for this study is composed of Greenbrier, Monroe, Pocahontas, and Summers Counties, West Virginia. As shown in Table 1, the population of the PSA grew through the 1970s to a maximum of 75,300 in 1983. Since 1983, the population of the PSA has declined by 7 percent to 70,300 persons in 1990.

About half of the PSA population lives in Greenbrier County. The 1990 population of Greenbrier County was 34,700. Pocahontas County, the largest county in the PSA, has the fewest inhabitants, numbering only 9,000 in 1990. Monroe and Summers Counties had 1990 populations of 12,400 and 14,200, respectively.

According to the BEA Regional Projections to 2040 (US Department of Commerce, October 1990), the population of the PSA is projected to grow very slowly. Population growth rates through 2040 are not expected to exceed 0.4 percent annually. By 2040, the population of the PSA is projected to exceed its historical maximum by only 1,500 persons.

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Table 1
Greenbrier River Basin Primary Study Area
Historical and Projected Population, 1973 - 2040

County	Historical					Projected					
	1973	1979	1983	1988	1990	1995	2000	2005	2010	2020	2040
Thousands of Persons											
Greenbrier County	32.7	37.0	37.1	35.0	34.7	34.9	35.1	35.5	36.1	37.6	38.3
Monroe County	11.4	12.6	13.0	12.6	12.4	12.4	12.4	12.5	12.7	13.2	13.3
Pocahontas County	8.7	9.9	9.6	9.2	9.0	9.0	9.1	9.1	9.3	9.6	9.7
Summers County	13.9	15.6	15.6	15.3	14.2	14.2	14.3	14.4	14.7	15.2	15.5
Totals	**66.7**	**75.1**	**75.3**	**72.1**	**70.3**	**70.5**	**70.9**	**71.5**	**72.8**	**75.6**	**76.8**
Annual Growth Rate											
Greenbrier County		2.1	0.1	-1.2	-0.4	0.1	0.1	0.2	0.3	0.4	0.1
Monroe County		1.7	0.8	-0.6	-0.8	0.0	0.0	0.2	0.3	0.4	0.0
Pocahontas County		2.2	-0.8	-0.8	-1.1	0.0	0.2	0.0	0.4	0.3	0.1
Summers County		1.9	0.0	-0.4	-3.7	0.0	0.1	0.1	0.4	0.3	0.1
Totals		**2.0**	**0.1**	**-0.9**	**-1.3**	**0.1**	**0.1**	**0.2**	**0.4**	**0.4**	**0.1**

Source: BEA Regional Projections to 2040 (October 1990), and 1990 Census of Population, US Department of Commerce.

Of the four major urban areas within the PSA, Hinton is the largest, with a 1990 population of 3,433. Ronceverte is next largest with a 1990 population of 1,754, followed by Alderson and Marlinton, with 1990 populations of 1,152 and 1,148, respectively.

C. <u>The Economy</u>. During the 1980's, employment in the PSA rose very slightly, even though the population was declining. Between 1979 and 1988, Pocahontas County showed the largest increase in employment, with a net gain of 700 jobs. Summers County shows a net loss of 600 jobs over the same period. Employment in Greenbrier County increased slightly and that of Monroe County remained unchanged. Table 2 shows historical and projected personal income, earnings, and employment in the PSA.

Constant dollar (real) earnings fell by 6 percent in the PSA between 1979 and 1988. Considering the increase in the number of jobs during the same period, this indicates that, overall, nominal earnings per job failed to keep pace with inflation and perhaps even declined. Real earnings rose only in Pocahontas County as the increase in employment overwhelmed the effects of declining real earnings per job. Earnings fell most dramatically in Summers County, from $52 million in 1979 to $37 million in 1988. Summers County is the only PSA county with declining total personal income and per capita personal income.

Services, government and retail trade are the three largest sectors of the PSA economy, together accounting for just over 60 percent of total employment and earnings in 1988. Other important economic sectors include manufacturing and agriculture, each accounting for more than 10 percent of total PSA jobs.

According to the <u>BEA Regional Projections</u> (1990), PSA employment is expected to decline slightly through 2040 with earnings growing slightly over the same period. Employment in services is projected to grow through 2040. Employment in retail trade is projected to grow through 2010, declining thereafter. PSA mining employment has the highest earnings per job, but is projected to decline to about 800 jobs by 2040.

PSA earnings are projected to grow at an annual rate of 0.8 percent through 2040. Over the same period, personal income is projected to grow at an annual rate of 1.2 percent, reflecting an increase in transfer payments or other unearned income, such as pensions.

In 1988, the ratio of earnings to personal income in the PSA was 53 percent, compared with 66 percent in West Virginia and 73 percent in the nation. By 2040, these ratios are projected to decline to 45 percent in the PSA, 56 percent in the state, and 67 percent in the nation.

Table 2
Greenbrier River Basin Primary Study Area
Personal Income, Earnings, and Employment by County
1973 - 2040

County	Historical				Projected					
	1973	1979	1983	1988	1995	2000	2005	2010	2020	2040
Per Capita Personal Income, 1982 Dollars										
Greenbrier County	7,109	8,379	8,062	9,159	10,317	10,990	11,548	12,053	12,992	15,481
Monroe County	6,222	7,142	6,982	7,981	8,900	9,420	9,860	10,274	11,059	13,193
Pocahontas County	6,388	8,163	8,121	9,113	10,393	11,140	11,777	12,366	13,428	16,102
Summers County	5,578	6,307	5,927	6,109	7,206	7,651	8,006	8,333	8,954	10,657
Greenbrier PSA	**6,544**	**7,708**	**7,450**	**8,302**	**9,461**	**10,062**	**10,583**	**11,032**	**11,899**	**14,198**
Total Personal Income, Millions of 1982 Dollars										
Greenbrier County	232.1	310.2	299.4	321.5	360.0	385.9	410.0	435.5	488.3	592.8
Monroe County	71.1	89.8	90.7	100.8	110.5	117.2	123.7	130.8	145.9	175.7
Pocahontas County	55.5	80.7	78.3	83.6	93.9	101.0	107.6	114.7	129.1	156.9
Summers County	77.8	98.2	92.6	93.5	102.6	109.3	115.4	122.1	136.3	165.0
Greenbrier PSA	**436.5**	**578.9**	**561.0**	**599.4**	**667.0**	**713.4**	**756.7**	**803.1**	**899.6**	**1,090.4**
Total Earnings, Millions of 1982 Dollars										
Greenbrier County	153.1	205.6	181.0	198.1	218.3	233.4	246.6	257.9	271.2	303.9
Monroe County	32.5	36.2	28.9	34.3	37.4	39.9	42.1	44.0	46.3	51.7
Pocahontas County	38.6	47.3	44.0	50.3	55.9	60.1	63.7	67.0	70.7	79.4
Summers County	45.1	51.7	40.0	37.0	39.9	42.2	44.2	46.0	48.1	53.8
Greenbrier PSA	**269.3**	**340.8**	**293.9**	**319.7**	**351.5**	**375.6**	**396.6**	**414.9**	**436.3**	**488.8**
Total Employment, Thousands of Jobs										
Greenbrier County	12.2	14.7	14.0	14.9	15.4	15.8	16.0	16.0	15.5	14.6
Monroe County	3.5	3.8	3.6	3.8	3.9	3.9	4.0	4.0	3.8	3.5
Pocahontas County	3.6	4.0	4.1	4.7	4.9	5.0	5.1	5.1	5.0	4.7
Summers County	3.8	4.3	3.8	3.7	3.7	3.7	3.8	3.7	3.6	3.3
Greenbrier PSA	**23.1**	**26.8**	**25.5**	**27.1**	**27.9**	**28.4**	**28.9**	**28.8**	**27.9**	**26.1**

Source: BEA Regional Projections to 2040 (October 1990), US Department of Commerce.

II. ECONOMIC IMPACTS OF FLOODING

A. Residential Structure Damage. A comprehensive inventory of flood-prone residential structures in the study area was completed in 1986. This inventory listed the type of construction, first floor elevation, and value of more than 1,300 residences in the study area.

In January 1994, the 1986 inventory was updated to account for changes in the type, number and value of flood-prone structures. Structures that have been destroyed by flooding, fire, or other means were removed from the inventory, new construction was added, and all structure values were updated to January 1994 price levels.

Content values were estimated at 50 percent of structure value for permanent dwellings and 30 percent of structure value for seasonal dwellings. These factors are based upon surveys conducted in 1986 in the Greenbrier River Basin PSA.

For purposes of this analysis, the Greenbrier River Basin has been divided into four reaches. The towns of Marlinton, Alderson, and Ronceverte are treated as separate reaches. The town of Hinton is not greatly affected by flooding of the Greenbrier River and is therefore not treated separately. Hinton and all of the intermediate areas between the urban reaches are treated as a single reach.

1. Number of Structures Affected. Nearly 1,300 of the residential structures located along the Greenbrier River are susceptible to damages from the 500-year frequency flood. One-third of these are seasonally-occupied structures such as hunting and fishing cabins. About half of the affected permanent residences are located in Marlinton and Alderson. A summary of the number of structures damaged by various levels of flooding is shown in Table 3.

Most of these structures are susceptible to damage at much lower levels of flooding. Almost half of the residential structures in the 500-year flood plain (49 percent) are susceptible to damages from the 10-year frequency flood. This includes 61 percent of the permanent residences in Alderson and 65 percent of those in Marlinton.

2. Value of Damage. Average annual flood damages to permanent and seasonal residential structures are $1,324,900. Alderson has the greatest concentration of flood damages, with average annual losses of over $500,000. Residential structures in Marlinton are also susceptible to severe flood problems, with average annual damages of nearly $250,000. Table 4 shows the average annual flood damages for residential structures in the Greenbrier River Basin.

Table 3
Number of Structures Susceptible to Flood Damages
By Structure Type and Level of Flooding

Flood Event	Structure Type	Number of Structures Damaged
1-Year	Residential	75
	Nonresidential	0
	Total	**75**
10-Year	Residential	632
	Nonresidential	102
	Total	**734**
20-Year	Residential	920
	Nonresidential	153
	Total	**1,073**
50-Year	Residential	1,082
	Nonresidential	218
	Total	**1,300**
100-Year	Residential	1,174
	Nonresidential	223
	Total	**1,397**
200-Year	Residential	1,218
	Nonresidential	250
	Total	**1,468**
500-Year	Residential	1,287
	Nonresidential	270
	Total	**1,557**

Table 4
Greenbrier River Basin
Average Annual Residential Flood Damages

Reach	Avg. Ann. Damages
Permanent	
Marlinton	242,700
Ronceverte	26,100
Alderson	536,600
Other	226,800
Total Permanent	**1,032,300**
Seasonal	
Alderson	4,800
Other	287,900
Total Seasonal	**292,700**
Total Residential	**1,324,900**

B. Nonresidential Structure Damage. The inventory of nonresidential structures was updated concurrently with that of residential structures. The value of the contents of nonresidential structures was determined at the same time. Expected flood damages to nonresidential structures are based on the updated structure inventory and reflect January 1994 price levels.

1. Number of Structures Affected. According to the updated structure inventory, 270 nonresidential structures are susceptible to damage at the 500-year frequency flood level. Almost 90 percent of these structures are located in the urban areas of Marlinton, Ronceverte, and Alderson, with about half located in Marlinton.

Large numbers of nonresidential units are damaged at lower levels of flooding. More than 200 structures are damaged by the 50-year flood and 153 structures by the 20-year flood. The number of nonresidential structures damaged by various levels of flooding are shown in Table 3.

2. Value of Damage. Average annual damages to nonresidential structures in the Greenbrier River Basin are $1,303,600. About 85 percent of these damages are to structures located in Marlinton and Ronceverte. Damages to commercial structures constitute more than half (53 percent) of the damages to nonresidential structures. Damages to industrial facilities constitute another 39 percent of damages to nonresidential structures. Table 5 shows the average annual flood damages in the Greenbrier River Basin.

C. Transportation Damages. Transportation damages are based on estimates of the number of miles of primary and secondary roads that are inundated by various flood events. Average damages per mile of damaged roadway are based on actual damages incurred in the 1985 flood. These values were updated to reflect January 1994 price levels using the ENR Construction Index. Average annual transportation damages at January 1994 price levels are $86,400. A summary of all flood control benefits is shown in Table 6.

D. Emergency Costs. Average emergency costs per damaged structure were computed, based on the 1985 flood. Prices were updated to January 1994 levels using the PCE Deflator. It was assumed that average emergency costs per structure would decrease as the level of flooding decreased and would equal zero for the 20-year flood and all lesser flood events. These average values were applied to the number of structures damaged by the various flood events to develop estimates of the average annual value of emergency costs. Average annual emergency costs at January 1994 price levels are $228,400.

E. Utility Damages. Utility damages include damages to electric, telephone, gas, water, sanitary, and storm sewer systems. Information on actual 1985 flood damages was obtained through contacts with utility companies and state and local officials. Prices were updated to January 1994 levels using the ENR Construction Index. Depth-damage functions were developed for each major facility in order to determine damage amounts for different flood levels. Damages to telephone equipment, which were scattered over a wide area, were correlated to the number of structures affected by each flood level. Average annual utility damages at January 1994 price levels are $252,000.

F. Reduction of Flood Insurance Administrative Costs. According to the Federal Emergency Management Administration (FEMA), 894 homes and businesses in the Greenbrier River Basin participate in the federal flood insurance program. The administrative cost of this program is an additional economic cost of flooding. FEMA reports annual administrative costs of $111,800 for the Greenbrier River Basin, or $125 per policy.

Table 5
Greenbrier River Basin
Average Annual Nonresidential Flood Damages
by Type of Industry

Reach	Avg. Ann. Damages
Commercial	
Marlinton	505,400
Ronceverte	38,100
Alderson	77,700
Other	76,400
Total Commercial	697,700
Industrial	
Marlinton	7,000
Ronceverte	497,400
Alderson	0
Other	100
Total Industrial	504,400
Municipal	
Marlinton	9,600
Ronceverte	21,500
Alderson	9,700
Other	5,500
Total Municipal	46,400

Table 5
Greenbrier River Basin
Average Annual Nonresidential Flood Damages
by Type of Industry
(Cont.)

Reach	Avg. Ann. Damages
Schools & Churches	
Marlinton	27,100
Ronceverte	4,800
Alderson	9,900
Other	5,500
Total Schools & Churches	47,300
Other	
Marlinton	6,800
Ronceverte	0
Alderson	0
Other	1,100
Total Other	7,900
Totals	
Marlinton	555,900
Ronceverte	561,800
Alderson	97,300
Other	88,600
GRAND TOTAL	1,303,600

Table 6
Greenbrier River Basin
Summary of Average Annual Flood Damages

Damage Category	Average Annual Damages
Residential Structures	$1,324,900
Nonresidential Structures	1,303,600
Flood Insurance Administration Costs	111,800
Interest on Loans for Uninsured Losses	192,500
Transportation Damages	86,400
Utility Damages	252,000
Emergency Costs	228,400
Total	**3,499,600**

G. Reduction of Interest on Loans for Uninsured Flood Losses. Many homes and businesses must obtain loans in order to repair flood damages. The interest paid on these loans is an additional cost of flooding. Information regarding the number and size of loans acquired subsequent to the November 1985 flooding of the Greenbrier River was obtained from the Small Business Administration (SBA). Average annual costs are based on the average loan interest costs per damaged structure and the number of structures damaged by each flood event. The average annual loan interest costs, at January 1994 price levels is $192,500.

III. ECONOMIC IMPACTS OF PROPOSED ALTERNATIVE PLANS

A. No Federal Action or Most Probable Without-Project Condition. The without-project condition assumes no action by the Federal government to implement any type of comprehensive flood damage reduction program in the study area. It reflects the continuation of existing economic, social, and environmental conditions and trends within the project area.

Inherent in the without-project condition is the continuation of Federally subsidized flood insurance coverage for property owners that is currently available through the National Flood Insurance Program and the enforcement of local floodplain zoning ordinances. The without-project condition requires no additional expenditures of Federal funds to implement comprehensive or partial flood damage reduction plans; however, current Federal expenditures subsidizing the flood insurance program and assisting in flood recovery operations continue.

B. Structural Alternatives. A total of three structural alternatives were evaluated. Alternative 1 is a dry dam providing 5" of flood control storage with minimum recreational development. Alternative 2 is a reservoir providing 5" of flood control storage with additional storage for a permanent pool and flow-augmentation releases. Alternative 2 also includes minimum recreational development. Alternative 3 is a dry dam providing 4" of flood control storage with minimum recreational development.

1. Alternative 1. Preliminary studies conducted in 1986 indicated that a dam providing 5" of flood control storage is the optimal project size for the Greenbrier River Basin. Alternative 1 consists of a dry dam located at river mile 119 and providing 5" of flood control storage. Flood control benefits for Alternative 1 are summarized in Table 7 and residual damages are summarized in Table 8.

Alternative 1 reduces damages to residential structures along the Greenbrier River by 90 percent, resulting in average annual benefits of $1,186,900. Average annual residual damages are $138,000.

This alternative also provides flood protection to residences located along the Kanawha and Ohio Rivers. Average annual flood control benefits attributable to reduced flooding of residences along the Kanawha River and Ohio River are $200,300 and $483,000, respectively.

Damages to nonresidential structures along the Greenbrier River are reduced by 98 percent, with average annual benefits of $1,268,400 and average annual residual damages of only $35,200.

Alternative 1 also provides protection to nonresidential

structures located along the Kanawha and Ohio Rivers. Average annual flood control benefits attributable to reduced flooding of nonresidential structures along the Kanawha and Ohio Rivers are $235,600 and $423,900, respectively.

Emergency costs and transportation damages are reduced by 98 percent under Alternative 1, with average annual benefits of $222,900 and $84,600, respectively.

Alternative 1 reduces the cost of administering the federal flood insurance program, since the number of residential and nonresidential structures in the 100-year floodplain declines by 56 percent. Assuming that the rate of participation in the federal flood insurance program does not change, this implies a similar reduction in the number of flood insurance policies and associated administrative costs. The resulting average annual benefits are $38,500.

The cost of interest on loans for uninsured flood losses is reduced significantly by Alternative 1. Damages to residential and nonresidential structures in the Greenbrier River Basin are reduced by more than 90 percent. A similar reduction in the number and size of loans and the associated interest payments yields average annual benefits of $176,200.

Average annual damages to utility equipment are reduced by $244,800 (97 percent) by Alternative 1.

Recreation benefits provided by Alternative 1 are largely due to improved access to the dam site and surrounding environs, and the construction of a fishing pier with handicap access. A detail description of the recreational facilities and the derivation of the benefits associated with the structural alternatives is included in Addendum 1 of this appendix. Average annual recreation benefits of this alternative are $60,900.

Employment benefits, based on $55.7 million on-site construction costs, were computed as directed by Planning Principles and Guidelines. Employment benefits associated with Alternative 1 are $799,100.

Overall, Alternative 1 reduces flood damages in the Greenbrier River Basin by 93 percent, with total residual damages of $253,300. Total average annual benefits for Alternative 1 amount to $5,449,100 and the total present value of benefits equals $68,083,200.

Table 7
Greenbrier River Basin
Summary of Benefits of Structural Alternatives
($1,000)

Benefit Category	Alternative 1	2	3
Residential Structures			
Greenbrier River	1,186.9	1,186.9	1,173.7
Kanawha River	200.3	200.3	178.6
Ohio River	483.0	483.0	464.7
Nonresidential Structures			
Greenbrier River	1,268.4	1,268.4	1,258.2
Kanawha River	235.6	235.6	207.4
Ohio River	423.9	423.9	399.8
Flood Insurance Admin.	62.5	62.5	60.9
Interest, Loans for Uninsured Losses	176.2	176.2	175.1
Transportation	84.6	84.6	82.1
Utilities	244.8	244.8	237.6
Emergency Costs	222.9	222.9	216.3
Recreation Benefits	60.9	161.1	60.9
Employment Benefits	799.1	1,031.9	980.4
TOTAL BENEFITS	5,449.1	5,782.1	5,495.8
PW @ 8 Percent, 100 Years	68,083	72,243	68,666

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Table 8
Greenbrier River Basin
Summary of Residual Damages of Structural Alternatives

Damages	Alternative 1	Alternative 2	Alternative 3
Residential Structures	138,000	138,000	151,200
Nonresidential Structures	35,200	35,200	45,400
Flood Insurance Administration Costs	49,300	49,300	50,900
Interest on Loans for Uninsured Losses	16,300	16,300	17,400
Transportation Damages	1,800	1,800	4,300
Utility Damages	7,200	7,200	14,400
Emergency Costs	5,500	5,500	12,100
TOTAL	253,300	253,300	295,700

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2. Alternative 2 Alternative 2 is identical to Alternative 1, with the addition of permanent storage for flow augmentation and recreational use. This alternative provides exactly the same flood control storage and flood control benefits as Alternative 1. Only two benefit categories, recreation and employment benefits, change under this alternative. Flood control benefits for Alternative 2 are summarized in Table 7.

Recreation benefits are larger, due to the expanded recreation opportunities that are afforded by a permanent lake. The facilities are essential the same as those included under Alternative 1. Average annual recreation benefits under Alternative 2 are $161,100.

Employment benefits of Alternative 2 are based on on-site construction costs of $71.9 million. Average annual employment benefits are $1,031,900.

Alternative 2 reduces total flood damages in the Greenbrier River Basin by 93 percent, with total residual damages of $253,300. Total average annual benefits for this alternative are $5,782,100, with a present value of $72,243,300. The average annual benefits and residual damages for Alternative 2 are summarized in Tables 7 and 8, respectively.

3. Alternative 3 Although previous studies indicated that a dam providing 5" of flood storage is the optimal size project for the Greenbrier River Basin, two smaller projects were also evaluated. Alternative 3 is a dry at river mile 119 dam that provides 4" of flood control storage. Alternative 3 also includes several design refinements that do not affect flood control capabilities, but that resulted in significant cost savings.

Alternative 3 is nearly as effective along the Greenbrier River as Alternatives 1 & 2, reducing flood damages 92 percent. Average annual flood damages to residential and nonresidential structures increase by only $115,700 under Alternative 3 as compared with Alternatives 1 & 2, and three-fourths of this increase is along the Kanawha and Greenbrier Rivers.

Recreation benefits provided by Alternative 3 are identical to those provided by Alternative 1, being attributable to improved access to the dam site and surrounding environs, and the construction of a fishing pier with handicap access. Average annual recreation benefits of this alternative are $60,900.

Employment benefits, based on $38.3 million on-site construction costs, were computed as directed by Planning Principles and Guidelines. Employment benefits associated with Alternative 3 are $900,400. Alternatives 1 & 2 reflect the use of conservative estimates of the share of total costs accounted for by on-site labor costs. Alternative 3 reflects the use of labor costs

taken from detailed engineering cost estimates, which contained a larger labor component than expected.

The average annual benefits and residual damages for Alternative 3 are summarized in Tables 7 and 8, respectively. Alternative 3 reduces total flood damages in the Greenbrier River Basin by 92 percent, with total residual damages of $295,700. The total average annual benefits of Alternative 3 are $5,495,800, with a present value of $68,666,300.

C. Nonstructural Alternatives. Preliminary studies indicated that traditional nonstructural alternatives appeared to be feasible for the Town of Marlinton. In this study, sixteen separate nonstructural alternatives were evaluated. In these alternatives, four levels of protection (10-yr., 20-yr., 50-yr. and 100-yr.) are considered for the three urban reaches and the rural Hinton-to-Buckeye reach.

The flood control benefits associated with the nonstructural plans are based on the estimates of flood damages used to evaluate structural plans. The benefits associated with the 10-year level of protection were estimated by assuming the elimination of damages resulting from the 10-year frequency flood and all lesser levels of flooding. Benefits for other plans were estimated in a similar manner. A summary of the benefits associated with the nonstructural plans is shown in Table 9.

Table 9
Greenbrier River Basin
Summary of Benefits of Nonstructural Alternatives
(January 1994 Dollars)

	10 YEAR	20 YEAR	50 YEAR	100 YEAR
AVERAGE ANNUAL BENEFITS:				
ALDERSON	$421,631	$513,369	$588,107	$595,708
RONCEVERTE	$141,082	$289,630	$446,937	$489,666
MARLINTON	$234,569	$369,751	$564,416	$656,576
HINTON-BUCKEYE	$277,996	$370,681	$478,075	$523,472
TOTAL	$1,075,278	$1,543,431	$2,077,535	$2,265,422

Other nonstructural alternatives include flood insurance, floodplain zoning and flood warning and emergency evacuation systems. All four counties in the study area are participants in the National Flood Insurance Program (NFIP) which mandates strict floodplain zoning ordinances.

Various local flood warning systems are currently in use in the Greenbrier River Basin. However, the basin does not have a comprehensive flood warning and emergency evacuation system. Such systems improve the ability of residents and businesses to relocate structure contents and other damageable property and to evacuate the floodplain prior to flooding. Consequently, they are effective both in reducing flood damages and in reducing the likelihood of flood-related fatalities. Five flood-related fatalities occurred during the 1985 flood.

The benefits and costs of a comprehensive flood warning and emergency evacuation system have not been evaluated. However, the cost of implementing such measures is relatively low, and an explicit evaluation of the feasibility of this plan is therefore warranted.